Terrestrial Magnetism

and

Atmospheric Electricity

(Now entitled Journal of Geophysical Research)

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AN INTERNATIONAL QUARTERLY JOURNAL

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PROGRAM OF SCIENTIFIC WORK ON CRUISE VII OF THE *CARNEGIE*, 1928-1931

By J. A. FLEMING AND J. P. AULT

After an interval of over six years, the *Carnegie* is to start out again on May 1, 1928, for a world-wide cruise extending over a period of three years. This will be the seventh cruise of the vessel and, as indicated by the tentative schedule below and Fig. 1, will add nearly 105,000 nautical miles to the present total of nearly 253,000 miles traversed in all oceans during cruises I to VI (1909-1921). A more general program of scientific work is to be undertaken than on previous cruises. In addition to investigations in terrestrial magnetism and atmospheric electricty, some work in physical and biological oceanography is to be attempted.

Thus the plans visioned in 1904 under the enthusiastic and energetic directorship of Dr. Louis A. Bauer for the worldwide magnetic and electric survey will be further realized. This work was begun during 1905 to 1908 on the chartered brigantine *Galilee* in the then magnetically unexplored Pacific under the command, respectively, of J. P. Pratt for the first cruise and of W. J. Peters for the second and third cruises. With the completion of the specially designed yacht *Carnegie* in 1909 the survey was continued with greater efficiency, because of the nonmagnetic construction of the vessel and of the steady evolution of suitable instruments and observational methods, in all oceans during 1909 to 1921 under the command, respectively, of W. J. Peters for cruises I and II, of J. P. Ault for cruises III, IV, and VI, and of H. M. W. Edmonds for cruise V.

The practical and theoretical value of the magnetic work already done on the *Carnegie* is attested by the principal hydrographic establishments of the world and by individual investigators. The full value of the data already obtained will now be enhanced by additional observations to determine the secular-variation (or progressive) changes of the Earth's magnetism.

While this information is needed for practical navigators, yet future magnetic work at sea is far more necessary for the advancement of theoretical studies. Accumulated data indicate that the accelerations in these secular-variation changes may not be extrapolated safely over periods as long as five years. Accurate and extended data are necessary for a number of epochs to advance the investigation of causes producing and laws governing these changes. Not only will observations be repeated in localities previouly surveyed by the *Carnegie*, but also additional information will be obtained regarding the distribution of the magnetic elements in some large areas not already covered.

Therefore, as heretofore, emphasis will be placed on observations in terrestrial magnetism. Experience during previous cruises has shown that results with certain methods and instruments are more reliable than with others, so that the duplication of instruments and methods need not be continued. Thus the magnetic declination will be determined by use of the marine collimating-compass, omitting the deflector; the horizontal intensity will be determined by the deflector, omitting the dip-circle method; the magnetic inclination will be determined with the earth inductor, omitting the dip circle.

Some minor improvements have been made in these instruments, chief among which is the addition of a constant-speed apparatus and drive for rotating the coil of the earth inductor, with amplifier and microammeter to measure the resulting electromotive force and inclination. It is hoped that this device may be adapted also to the measurement of the horizontal intensity, thus replacing the more laborious deflector-method with a more rapid and accurate electric method.

For the further investigations on the origin and maintenance of the Earth's electric charge and of its relation to the Earth's magnetic condition, additional determinations of changes in the values of the atmospheric-electric elements with geographic position are needed. Recent investigations of the penetrating radiation, or of the so-called "cosmic rays," emphasize the need of additional observations of the ionization of the air over the oceans. Further widely distributed determinations of the diurnal variations in atmospheric potential-gradient are needed to confirm the conclusion that such variations progress with universal time (a deduction first indicated from results obtained on the *Carnegie*) and to test theories and hypotheses concerned therewith. The important contribu-

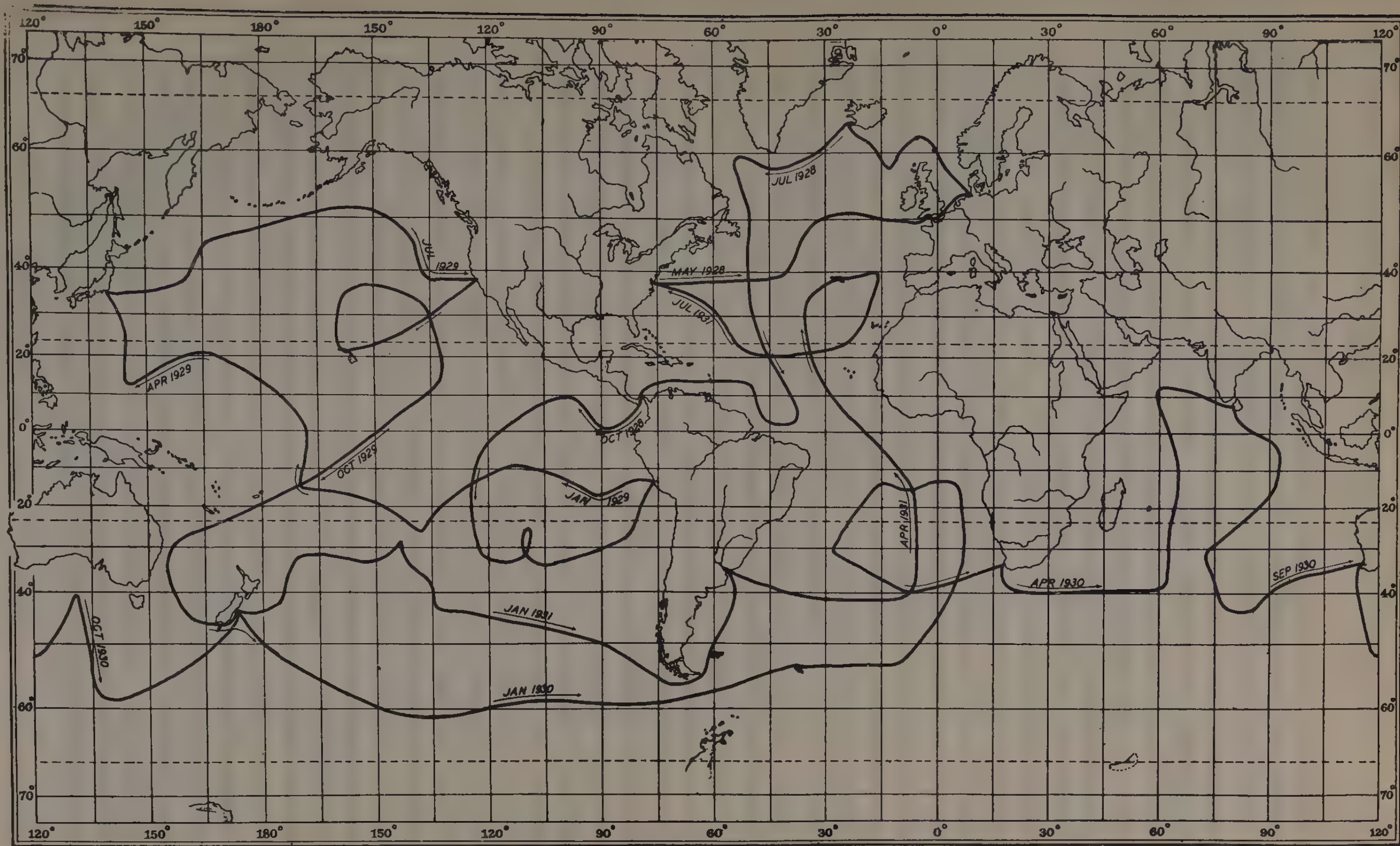

FIG. 1—Tentative route for seventh cruise of the *Carnegie*, 1928 to 1931

tions to the study of various geophysical problems which are being made by investigations of the Kennelly-Heaviside conducting layer and of radio transmission and variations with changing magnetic and electric conditions, greatly enhance the value of the atmospheric-electric data already collected on the *Carnegie* over the ocean areas, and indicate cooperative investigations along similar lines for the coming cruise. The study of earth-currents at the observatories of the Carnegie Institution of Washington has become of sufficient importance to warrant the attempt of similar observations at sea.

In the atmospheric-electric work, automatic photographic methods will be used to continuously record variations in the potential gradient and the conductivity. The new automatic photographic-recording electric potential-gradient recorder will be mounted near the top of the mainmast while the eye-reading apparatus will be mounted on the quarter-deck railing as heretofore for control observations. A motor has been installed in the ionic-content apparatus in place of the spring and clock-work mechanism for drawing the air through the instrument. Some improvements have been made in the instruments and methods for measuring the penetrating radiation and the radioactive content, and more frequent series of observations extending over a period of 24 hours are planned. In addition to the program previously followed for observations of the penetrating radiation, parallel observations will be made with a Kolhörster instrument which Dr. Kolhörster is thoroughly testing and comparing with his "standard" instrument. It is planned to observe especially for variations with time, with geographical position, and with depth. These, together with the oceanographic determinations of salinity, temperature, etc., should assist toward a determination of the cause of such variations as have been observed heretofore and should aid in appraising several theories. Dust-count observations, using an Aitken dust-counter, will be made for correlative studies with atmospheric electricity. The measurement of marine electric currents will be attempted by trailing electrodes on cables from the stern of the vessel.

Since the magnetic work on the coming cruise is primarily to secure secular variation in terrestrial magnetism, the route will follow as closely as practicable the routes of previous cruises. This will insure a maximum of valuable data as to progressive changes covering the period 1905 to 1930. Thus it will not be necessary to

carry out the program of magnetic work except on alternate days since, in general, previous cruises have provided a very good distribution of stations. This, together with the omission of duplication of methods and instruments previously mentioned, and the arrangements to add two men to make a total of eight in the scientific personnel, has made it possible to include physical and biological oceanography as a part of the scientific program.

In physical oceanography it is planned to investigate the topography and configuration of the ocean-depths by the sonic depth-finder; to study the causes of movements of vast bodies of water relatively to one another, the dynamics of the sea, by measuring differences in temperature and salinity over the surface and at various levels down to a maximum of 20,000 feet; to secure information regarding the nature and derivation of inorganic marine deposits by sampling the bottom muds and sediments; and to increase our knowledge of the physical interchange between the surface of the ocean and the air above it by measuring the temperature and humidity lapse-rates of the air in the first 100 feet above the surface, and by observing the variations in the amount of solar radiation received at the ocean surface.

Work in marine biology will be confined to microbiology, to determine the abundance and distribution of plankton and other small organisms. Shallow-water dredging will be undertaken to secure diatoms and foraminifera, and specimens of porpoises, dolphins, birds, and other creatures will be collected from special regions.

To carry out this program of oceanographic investigation and to provide for new equipment required many changes in the *Carnegie*. The structural changes were made during the summer of 1927, when the vessel was completely overhauled and repaired at the Tietjen and Lang shipyard, Hoboken, New Jersey. A new stateroom was added in the cabin to provide quarters for the chemist and biologist, and quarters were provided for a radio operator. The two lifeboats were removed from the quarter-deck to overhead platforms amidships opposite the after dome, thus leaving the quarter-deck free for the operation of the winch, sounding wire, water-bottles, deep-sea reversing thermometers, tow-nets, bottom-samplers, evaporation equipment, and earth-current cables. The special equipment needed for the various phases of the work was added after the return of the vessel to Washington. Some of this equipment was made in the instrument-shop of the Department of Terrestrial Magnetism at Washington, this being especially the case

TABLE 1—*Tentative schedule for Cruise VII of the Carnegie, 1928-1931*

Port	Leave	Distance miles	Miles per day	Days at sea	Oceanographic work[1] days	Port	Arrive	Days in port
	1928						1928	
Washington	May 1	3700	150	25	3	Plymouth	May 29	10
Plymouth	Jun. 8	500	100	5	0	Hamburg	Jun. 13	10
Hamburg	Jun. 23	1600	100	16	2	Reykjavik	Jul. 11	10
Reykjavik	Jul. 21	6500	130	50	5	Barbados	Sep. 14	15
Barbados	Sep. 29	1300	150	9	1	Balboa	Oct. 9	5
Balboa	Oct. 14	6700	130	52	5	Easter Is	Dec. 10	10
							1929	
Easter Is	Dec. 20	2500	140	18	2	Callao	Jan. 9	20
	1929							
Callao	Jan. 29	4400	140	31	3	Papeete	Mar. 4	5
Papeete	Mar. 9	1300	130	10	1	Apia	Mar. 20	20
Apia	Apr. 9	4000	140	29	3	Guam	May 11	5
Guam	May 16	1500	120	13	1	Yokohama	May 30	25
Yokohama	Jun. 24	4800	150	32	3	San Francisco	Jul. 29	25
San Francisco	Aug. 23	2200	150	15	2	Honolulu	Sep. 9	10
Honolulu	Sep. 19	5900	110	54	5	Apia	Nov. 17	15
							1930	
Apia	Dec. 2	4200	120	35	4	Lyttelton	Jan. 10	20
	1930							
Lyttelton	Jan. 30	5500	160	34	3	South Georgia	Mar. 7	2
South Georgia	Mar. 9	4300	150	29	2	St. Helena	Apr. 9	10
St. Helena	Apr. 19	4500	150	30	2	Cape Town	May 21	20
Cape Town	Jun. 10	6700	150	45	5	Colombo	Jul. 30	20
Colombo	Aug. 19	3600	140	26	3	St. Paul	Sep. 17	2
St. Paul	Sep. 19	2300	140	16	2	Fremantle	Oct. 7	25
Fremantle	Nov. 1	4600	140	33	3	Lyttelton	Dec. 7	20
							1931	
Lyttelton	Dec. 27	2800	120	23	2	Rapa Is	Jan. 21	2
	1931							
Rapa Is	Jan. 23	5500	120	46	5	Buenos Aires	Mar. 15	25
Buenos Aires	Apr. 9	4100	120	34	3	St. Helena	May 16	10
St. Helena	May 26	4000	130	31	3	Ponta Delgada	Jun. 29	5
Ponta Delgada	Jul. 4	1200	120	10	1	Madeira	Jul. 15	2
Madeira	Jul. 17	4200	100	42	4	Washington	Sep. 1	..
Totals	....	104400	...	793	78	....	......	348

[1]Allowing 4 to 5 hours every other day at sea for stopping the vessel at oceanographic stations.

for the magnetic, atmospheric-electric, and electric apparatus. The special oceanographic equipment for deep-sea work is largely of German and Norwegian manufacture.

Two new laboratories were constructed on the main-deck, one designed for oceanographic investigations, and one for radio and sound work. In the oceanographic laboratory are mounted the Wenner electric salinity apparatus, the Negretti and Zambra distant-recording surface-temperature thermograph operating on a 24-hour rate, and the various equipment and apparatus for the study of plankton and of the chemistry of the air and of sea-water.

In the radio and sound laboratory is mounted the depth-finder loaned by the United States Navy Department for measuring rapidly and accurately the depths of the sea. The short-wave transmitting and receiving radio equipment made after the design of the United States Naval Research Laboratory, for the investigation of variations in transmitting and receiving conditions and of skip-distances and signal-intensity is installed in this laboratory.

A new galvanometer house was built on the port side of the quarter-deck aft of the radio laboratory in place of the one removed to make room for the winch. The Einthoven-type string galvanometer for the earth inductor and for the earth-current apparatus, control portion of the constant-speed apparatus, amplifying unit and microammeter, special inductance-coils, and appurtenances for the earth-inductor work, the recording apparatus for six resistance-thermometers located at various places from the masthead to near the ocean surface, and the roll-and-pitch recorder, are mounted in this house.

It is planned to obtain water-samples and temperatures at depths of 5, 25, 50, 75, 100, 200, 300, 400, 500, 700, 1,000, 1,500, and 2,000 meters every 150 to 200 miles, with series down to the bottom with a limit at 20,000 feet every 600 to 800 miles. Nansen water-bottles of one and one-quarter liter capacity and Richter and Wiese reversing deep-sea thermometers will be used for securing water samples and temperatures.

A 30-horsepower gasoline engine, a 12-kilowatt generator, and a 320-ampere-hour storage battery have been installed in the engine-room below decks to furnish the electric power to operate the new three-ton bronze winch on deck. Two reels and two gypsy-heads are provided, one reel containing 20,210 feet of special aluminum-bronze stranded wire rope 3/16 inch or 4 mm. in diameter and the other containing 6,808 feet of 1/4-inch or 6 mm. wire. This wire was made in Germany and was designed especially for oceanographic work after extensive tests and experiments by those in charge of preparations for the German Atlantic Expedition on the *Meteor* during 1925 to 1927.

The reels may be operated either singly or together, thus allowing one wire to be payed out on the brake while the other wire is being hauled in. This will allow two series of water-bottles, 10 on each line, to be operated simultaneously, or vertical tow-nets may be handled on the heavier line, while a series of water-samples and temperatures are being taken on the other.

The gypsy-heads will be used in handling yards and sails, hoisting life-boats, hauling in earth-current cables, towing surface or deeper horizontal tow-nets, and in general deck-work. Special bronze davits and blocks have been installed on port and starboard sides and at the stern for handling the bronze wire as it is payed out or hauled in. Platforms have been constructed on both port and starboard sides, where the operator will stand while attaching the water-bottles and thermometers to the sounding wire or detaching them.

The sonic depth-finder was installed on board the *Carnegie* during the repairs in Hoboken. The oscillator is in the bottom of the keel directly below the engine-room, 17 feet, 3 inches, forward of the stern-post. It has a steel diaphragm 30 inches in diameter to operate at a frequency of 540 cycles and is rated at 110 volts, 3 amperes direct current, and 180 volts, 11 amperes alternating current. The brass tube carrying six microphones is 13 feet long and is located 45 feet, 10.5 inches forward of the oscillator along the keel below the garboard strake on the port side. The tube is well perforated to allow ready access of sound waves, and both oscillator and microphone tubes are housed in with heavy oak sheathing covered over with sheet copper. The oscillator has sheet lead 18 inches wide immediately around it to reduce the electrolytic action.

The depth-finder, designed by Harvey C. Hayes for the United States Navy, is installed in the new radio laboratory on the main-deck. The necessary 5-kilowatt motor-generator outfit with automatic starter and control-panel, all rated for 90-150 volts direct current, are installed in the engine-room. This depth-finder is designed to operate for all depths greater than 100 fathoms.

Various sizes and types of bottom-samplers will be used, including a modified Ekman, a Sigsbee tube with detachable weight, and both small and large mud-snappers. It is planned to secure bottom-samples every time the wire is sent to the ocean bed, up to the full length of the longer wire, namely, 20,000 feet.

The meteorological equipment is housed in a new and larger shelter-house constructed on the quarter-deck in place of the one used on previous cruises. The equipment includes thermograph and other recording instruments, psychrometers, and thermometers for measuring air and surface-water temperatures. The Hartmann and Braun recorder for six resistance-thermometers (three of which will give wet-bulb temperatures) is to be mounted in the new galvanometer house when the vessel reaches Hamburg. The resistance-

thermometers will be located at various points on the vessel, including top and middle mainmast and shelter-house (both wet- and dry-bulb temperatures). The temperature and humidity lapse-rates from sea-surface to masthead it is hoped may be accurately measured by this equipment. A wet- and dry-bulb type recording thermometer using the aspiration principle of Assmann by Negretti and Zambra is to be installed at Plymouth, England, in the shelter-house. Rainfall, evaporation, solar radiation, and dust-content and carbonic-acid-content of the atmosphere will be measured also. It is hoped that, despite the difficulties of such work on a sailing vessel, data on the general upper-air circulation may be obtained by pilot-balloon flights for which equipment is provided.

In the biological work, most of the collecting will be done by tow-nets and dip-nets. A special boom-walk, similar to the one used by Beebe, has been installed on the starboard forward side of the vessel, where the collector may walk 30 feet out from the side of the ship on a plank suspended by a netting of rope from two boat-booms and about three feet below them. The booms are hinged at the rail and are suspended from the mast by a pendant and have preventer-stays both forward and aft. Thus surface collections may be made both with dip-nets and with surface tow-nets well away from the wash of the ship. To assist the biologist in his study of marine life in its native habitat at the bottom of the ocean, a diving helmet has been secured for use in shallow water. Limited space on the *Carnegie*, lack of time on the cruise as planned, and restrictions as to power and proper machinery prohibit undertaking any deep-sea trawling or dredging.

It is planned to compute at sea and publish promptly, as the cruise progresses, the pertinent oceanographic data for use of students and investigators of oceanography, as has been done heretofore and will be continued in terrestrial magnetism and atmospheric electricity. The physical data to be published include the following results of observations and calculations at various depths: temperature, salinity, density observed and corrected for compression, oxygen-content, hydrogen-ion concentration, specific volume, and dynamic pressure and depth. The dynamic calculations will be made in accordance with the method devised by Bjerknes and as modified by Hesselberg, Sverdrup, and others.

Interested organizations will be furnished with water-samples, bottom-samples, marine biological specimens, and rock and bird specimens from countries and islands visited for special study and report. A final discussion and publication of the results of the cruise

will be made by the Carnegie Institution of Washington at the conclusion of the work.

The total number of personnel required aboard for the expedition is 25. The scientific staff of eight as now constituted includes the following: Captain J. P. Ault, commander, and chief of scientific staff; Wilfred C. Parkinson, senior scientific officer (atmospheric electricty and photography); Oscar W. Torreson, navigator and executive officer (magnetism, navigation, and meteorology); F. M. Soule, observer and electrical expert (magnetism and physical oceanography); H. R. Seiwell, chemist and biologist (oceanography); J. H. Paul, surgeon and observer (medical work, meteorology, and oceanography); W. E. Scott, observer (navigation and commissary); Lawrence A. Jones, radio operator and observer (radio investigations and communications). We are fortunate in again having obtained the services of three officers of the sailing staff who were on board the entire two years of the last cruise of the vessel. They are: Mr. A. Erickson, first watch-officer; Mr. C. E. Leyer, chief-engineer; and Mr. F. Lyngdorf, steward.

Any statement of the proposed program would be incomplete without mention of the generous cooperation, expert advice, and contributions of special equipment and books received on all sides from interested organizations and investigators both in America and in Europe. Among these the Carnegie Institution of Washington is indebted to the following: United States Navy Department, including particularly its Hydrographic Office, Naval Research Laboratory, Signal Corps and Air Corps of the War Department, National Museum, Bureau of Fisheries, Weather Bureau, Coast Guard, and Coast and Geodetic Survey; Scripps Institution of Oceanography of the University of California; Museum of Comparative Zoology of Harvard University; School of Geography of Clark University; American Radio Relay League; Geophysical Institute, Bergen, Norway; Marine Biological Association of the United Kingdom, Plymouth, England; German Atlantic Expedition of the *Meteor*, Institüt für Meereskunde, Berlin, Germany; British Admiralty, London; Carlsberg Laboratorium, Bureau International pour l'exploration de la Mer, and Laboratoire Hydrographique, Copenhagen, Denmark; and many others. Dr. H. U. Sverdrup of the Geophysical Institute at Bergen, Norway, research associate of the Carnegie Institution of Washington, is consulting oceanographer and physicist.

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THE ORIGIN OF THE AURORA BOREALIS

By E. O. Hulburt

A theory of the aurora borealis has been developed by Birkeland, Störmer, Vegard,[1] and others on the assumption that the aurora is caused by charged particles emitted from the Sun which under the influence of the magnetic field of the Earth are diverted to the polar regions. There their energy is given to the atmosphere and by some process is converted partially or totally into the auroral light. In the theory a difficulty has existed for a long time which, it must be said, has not been very troublesome because of the rather tentative nature of the theory. If the charged particles are α-particles or ions of some sort they do not combine a sufficient penetrating power with a sufficient magnetic deflectibility to explain the height and structure of the aurora,[2] and if they are electrons their penetrating power may be too great.[3]

Other difficulties, somewhat indirect perhaps, have been brought out by Rayleigh[4] in his experiments on the aurora-spectrum. He photographed the spectrum during the display of March 14, 1922, and then tried, without success, to produce a similar spectrum by exciting nitrogen in a vacuum-tube with atomic rays and with electron rays. The energy-distribution of the nitrogen lines and bands of the aurora-spectrum was quite different from that of the laboratory vacuum-tube sources. Spectra of mixtures of helium and nitrogen under ray excitation gave always the lines of helium; these lines were noticeably absent in the aurora-spectra, although helium is undoubtedly present in the upper atmosphere in appreciable quantity.[5]

It is the purpose of this paper[6] to give a slightly different explanation of the origin of the auroral-energy which seems on the whole more probable and perhaps more reasonable than the earlier views. The idea has come out of a recent theoretical examination of the ionization of the upper atmosphere of the Earth.[7] As in Birkeland's

[1] Vegard, *Phil. Mag.*, 23, 211 (1912); see also Gehrke, Handbuch der Physikalischen Optik, II, 178 (1927).

[2] Vegard, *Phil. Mag.*, 46, 211 (1923).

[3] Swann, *Phil. Mag.*, 47, 306 (1924).

[4] Rayleigh, *Proc. Roy. Soc.*, 101, 114 (1922).

[5] Chapman and Milne, *Roy. Meteor. Soc.*, 46, 357 (1920).

[6] A shorter version of this paper is in the *Physical Review* for June 1928.

[7] Hulburt, *Phys. Rev.*, June 1928.

theory the energy of the aurora is conceived as coming from the Sun. It is borne to the Earth not by flying charged particles but by ultra-violet light. A part of the ultra-violet light from the Sun is absorbed in the high atmosphere of the Earth and produces ions and electrons. These charged particles diffuse with little recombination because of the low pressure; during the diffusion there will be always equal numbers of positive and negative charges in each cubic centimeter of the atmosphere, for, due to the electrostatic fields which would arise, no great separation of positive and negative charges can occur. (The other paper[7] should be referred to for a more complete discussion of the diffusion of the ions and electrons in the upper atmosphere.) At great heights, above 200 km., say, where the frequency of collision is small the diffusion of the ions across the magnetic field of the Earth is slow compared to the drift along the field, and there will be a rapid migration of the ions to the polar regions and a concentration there. They move to lower levels and recombine, setting free their energy of recombination which in some way causes the aurora. Thus the energy of that portion of the Sun's ultra-violet light which is absorbed at high levels in the sun-lit regions is transported to the polar regions and reappears (or a portion of it does) as auroral light. The ions may be regarded as being vaporized in the high atmosphere, and distilled along the lines of magnetic force to the poles where they condense to neutral molecules again and yield up their energy of formation as auroral light. Störmer's[8] recent discovery of an aurora which appeared in that part of the high atmosphere directly illuminated by the Sun is in keeping with the present ideas, although of course this daylight luminosity may differ in many ways from the night aurora.

A very rough quantitative estimate of the intensity of the aurora illumination was made at Chebeague Island, Maine, during the strong display of August 20, 1927. The greenish arc of the aurora was visible low in the north from which faint streamers emanated southward; shifting clouds of faint luminosity pervaded the northern hemisphere of the sky. A crescent moon was sinking in the west, and I observed that the auroral radiance was slightly weaker than the moonlight. By means of a flourescent screen and a piece of black glass, opaque to visible light, but which transmitted ultra-violet radiations below 400 $\mu\mu$ the aurora was seen to be no brighter in the ultra-violet than the moon. The ratio

[8]Störmer, *Nature*, 120, 329 (1927).

of ultra-violet to visible light appeared to be greater for the aurora than for the moon. These observations were taken to mean that the energy of the auroral light was 10^{-2} of that of full moonlight, or 10^{-2} erg cm^{-2} sec^{-1}. The total area illuminated by the aurora was taken to be 10^{-2} of the surface of the Earth or 5×10^{16} cm^2. Therefore the total energy of the auroral light upward and downward was $2\times10^{-2}\times5\times10^{16}=10^{15}$ erg sec^{-1}.

In the ionization calculation[7] it has been shown that 4.5×10^{-3} erg cm^{-2} sec^{-1} of ultra-violet solar energy may reasonably be expected from the Sun in that region of the short ultra-violet wavelengths which cause ionization of the oxygen or nitrogen of the atmosphere, and that the ionization which is produced agrees with that indicated by the experiments of wireless telegraphy. The target area of the earth is πR^2 or 1.3×10^{18} cm^2. Therefore the solar ultra-violet energy which falls upon the whole Earth and causes ionization is $4.5\times10^{-3}\times1.3\times10^{18}=6\times10^{15}$ erg sec^{-1}. It is reasonable to assume that 10^{-2} of this goes into the high-lying ion pairs which move to the polar regions. Therefore an energy 6×10^{13} erg sec^{-1} is available for the aurora, under the ordinary solar influence, and in times of sunspot-activity may be much more. This is near enough to the value 10^{15} erg sec^{-1}, which was for an unusually strong auroral display, to support the present view.

Because of the winds in the high atmosphere of the Earth and of variations in the solar radiation due to sunspots, etc., the ion-layer is probably not uniform but is a thing of shreds and patches. Upon drifting to the poles the patches lengthen into streaks and, being touched into luminosity, form the auroral streamers. But here I must stop, partly to avoid being too rash, but mainly to admit that my contemplation of the aurora has been too limited to give that steadying of ideas which comes only from experimentation.

NAVAL RESEARCH LABORATORY,
Washington, D. C.,
March 29, 1928.

REVIEWS AND ABSTRACTS

(See also pages 52 to 57)

F. Aguerrevere: *Declinación magnética en Venezuela desde 1700. Curva de declinación en 1913. Tablas de declinación magnética aproximada en toda la República.* Caracas, Ministerio de Relaciones Exteriores, 1927 (14 pp., 1 curva y 1 mapa). 23 cm.

Students of terrestrial magnetism will note with much satisfaction the publication of this pamphlet by Dr. Aguerrevere, not only because it is a contribution from a country in which the magnetic conditions are so imperfectly known but also because the advance of our knowledge of the Earth's magnetism must depend largely on such studies pertaining to limited localities which may furnish material for a discussion of the problem as a whole.

The paper sets forth the results of a study of the secular variation in Venezuela from 1700, the date of the earliest available information regarding the magnetic declination (Halley's well-known variation chart) down to the year 1922. The curve representing the change for Caracas is based, however, on eight values only, of which five fall within the period 1893-1922. In spite of the fact that the curve, particularly for the first hundred years, rests upon extremely meager information, the author believes that it represents the general trend of the phenomenon over the period examined. On the assumption that the putative secular-variation cycle begins for Caracas about 1700, he is led to suspect that this city is at present near the middle of the half-cycle, which he estimates to be 500 years with an amplitude of 20°. This period is considerably in excess of those found by the United States Hydrographic Office for points not very far distant from Caracas, *e. g.* for Curaçao and Mexico City, where the full cycle was computed to be 360 years.

Although the tables of approximate declination values at various places for different years and the map showing the lines of equal magnetic declination for the year 1913 in Venezuela, have been prepared with the aid of all available data, the paucity of observational results in certain parts of the country renders difficult even an approximate delineation of the isogonics for those regions, thus emphasizing the need of more detailed magnetic surveys. While the pamphlet is primarily intended for the practical needs of surveyors for whom certain directions regarding the use of the tables are given, the results of such studies cannot fail to be of assistance also to geophysicists who concern themselves with theoretical considerations of terrestrial magnetism.

H. D. Harradon.

SOME OBSERVATIONS OF ATMOSPHERIC-ELECTRIC POTENTIAL-GRADIENT ON MOUNTAIN PEAKS IN THE PERUVIAN ANDES NEAR HUANCAYO, PERU

By W. C. Parkinson

Abstract.—In order to supplement the scanty data on atmospheric potential-gradient on mountain peaks, continuous records were obtained at two stations near the Huancayo Magnetic Observatory of the Department of Terrestrial Magnetism. The first station (Matahuata) was 500 feet and the second (Cerro-de-Ahuac) was 2,200 feet above the Observatory. Curves showing the diurnal variation during fine weather at the two stations and also at the Observatory base-station are given and briefly discussed.

Observations of the electrical potential of the air on the summits of mountains have been made at various times by various observers[1]. These observations, however, were made with eye-reading instruments, they cover only daylight hours, and extend only over a few days. A longer series of observations, made with self-recording instruments on the summit of the Pic du Midi, is described by Marchand.[2]

An opportunity to supplement such data presented itself during the time that the writer was stationed at the Huancayo Magnetic Observatory of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington. This Observatory itself, where continuous registration of electric air-potential is made, is situated on a fairly level plain, 11,000 feet (3,353 meters) above sea-level, between the central and eastern cordilleras of the Peruvian Andes. About one mile to the north of the Observatory is a prominent hill called Matahuata of conical shape and standing 500 feet (152 meters) above the surrounding plain; here, for three weeks during May, 1927, potential-gradient observations were made. Between June 6 and July 5, 1927, observations were made at the station (see Fig. 1) on the summit of one of the ridges called Cerro-de-Ahuac comprising the central cordillera, a point about 3.7 miles southwest of the Observatory and 2,200 feet (671 meters) above it or roughly 13,000 feet (3,963 meters) above sea-level. Between May 1 and May 7, and again between July 6 and 20, observations were made on the Observatory site itself at the regular standardizing field-station (designated B) for comparison with the Observatory standard potential-gradient recorder.

[1]W. Saake, Messengen des elektrischen Potentialgefälles der Elektrizitätszerstreuung und der Radioaktivität der Luft im Hochtal von Arosa (Schwiez). *Physik. Zs.*, v. 4, No. 23, 1903 (626-632).
W. Marten und K. Kähler, Aktinometrische und luftelektrische Messungen im Riesengebirge. *Veröff. Met. Inst.*, No. 256, 1913 (119-132).

[2]E. Marchand, L'électricité Atmosphérique au Pic du Midi. *Annu. Soc. Météor.*, v. 54, May 1906 (137-146).

Fig. 1—Potential-gradient station at Cerro-de-Ahuac near Huancayo, Peru

The apparatus used for the work consisted of a Wulf bifilar electrograph (Günther and Tegetmeyer No. 4947) giving a continuous photographic record, connected to an ionium-collector suspended one meter above the ground by the stretched-wire method. The recording instrument, batteries, and appurtenances were housed in a frame structure covered with canvas and so built as to be readily disassembled and carried by mules up the steep mountain paths. This house was seven feet above ground at its highest point and was sufficiently removed from the collector as not to distort the equipotential lines in the vicinity. For the same reason,

Table 1—*Hourly values in volts per meter of potential gradient at Matahuata field-station*

Date *1927*	75th meridian time west in hours											
	0–1	1–2	2–3	3–4	4–5	5–6	6–7	7–8	8–9	9–10	10–11	11–12
May 19	65	49	51	44	30	16	22	84	136	190	210	207
20	25	23	16	16	21	21	25	61	131	181	188	170
22	63	62	61	31	14	30	44	70	120	130	130	131
23	62	60	58	56	53	22	29	85	143	193	197	182
24	36	37	35	39	46	43	48	110	206	259	262	234
25	61	59	65	64	57	56	66	143	185	256	272	201
28	66	58	66	57	53	32	30	40	48	33	107	148
29	71	68	64	62	65	67	70	118	152	166	198	235
30	82	79	50	47	51	55	59	90	143	195	287	281
31	64	66	64	60	60	56	66	85	118	150	182	190
June 1	65	66	72	70	60	62	74	157	203	246	284	288
Means	60	56	55	50	46	42	48	95	144	182	211	206

75th meridian time west in hours												
12–13	13–14	14–15	15–16	16–17	17–18	18–19	19–20	20–21	21–22	22–23	23–24	0–24
182	164	131	134	100	58	67	61	61	53	28	27	90
135	116	103	80	101	90	104	70	68	62	49	58	80
139	154	146	122	99	82	80	68	58	50	53	63	83
183	152	167	144	121	91	91	84	67	60	53	37	100
223	200	172	130	120	104	108	94	79	80	69	68	117
188	174	160	144	129	114	88	74	74	65	69	59	118
161	130	98	95	104	81	65	60	56	53	58	65	74
217	139	109	111	105	90	124	91	86	90	85	90	111
257	171	138	121	118	80	146	68	60	56	62	62	111
208	190	160	140	120	110	103	87	81	68	76	69	107
270	250	190	161	138	125	124	105	104	100	100	92	142
197	167	143	126	114	83	91	78	72	67	64	63	102

TABLE 2—*Hourly values in volts per meter of potential gradient at Huancayo Magnetic Observatory* (values reduced to infinite plane by application of reduction-factor 1.07)

Date *1927*	75th meridian time west in hours											
	0–1	1–2	2–3	3–4	4–5	5–6	6–7	7–8	8–9	9–10	10–11	11–12
May 19	17	19	18	19	17	17	27	45	62	86	107	92
20	19	15	17	16	19	14	17	40	72	87	85	85
22	16	19	17	14	13	14	15	30	49	62	61	60
23	17	17	14	17	16	14	17	48	67	103	98	89
24	15	16	20	20	21	20	17	75	109	135	117	120
25	17	20	20	20	19	17	25	52	68	96	132	101
28	21	18	20	19	18	18	21	43	39	70	68	77
29	18	17	17	16	17	17	21	46	64	80	89	116
30	47	45	47	43	39	44	46	80	154	175	171	150
31	21	26	22	22	20	20	25	41	63	80	96	92
June 1	22	21	18	19	18	19	26	35	105	121	133	146
Means	21	21	21	20	20	19	24	48	77	100	105	103

75th meridian time west in hours												
12–13	13–14	14–15	15–16	16–17	17–18	18–19	19–20	20–21	21–22	22–23	23–24	0–24
80	91	63	57	49	26	26	21	22	22	11	19	43
72	55	45	24	42	32	27	24	25	19	17	17	36
72	72	66	55	43	32	19	19	21	15	19	21	34
81	74	86	72	52	41	43	31	22	19	16	16	45
100	92	70	57	48	46	50	40	31	32	22	21	54
78	83	68	62	59	51	40	30	19	21	16	17	47
80	63	59	46	44	30	32	27	21	14	17	15	36
94	64	50	59	56	54	50	50	47	50	47	45	49
134	101	67	59	42	32	39	30	26	19	30	21	68
94	87	80	67	55	30	25	37	30	18	19	18	45
122	106	82	70	62	24	31	30	24	24	35	30	56
92	80	67	57	50	36	34	31	27	24	22	22	47

TABLE 3—*Hourly values in volts per meter of potential gradient at Cerro-de-Ahuac field-station*

Date 1927	75th meridian time west in hours											
	0–1	1–2	2–3	3–4	4–5	5–6	6–7	7–8	8–9	9–10	10–11	11–12
June 12	107	104	103	105	69	36	22	63	193	278	301	307
14	81	78	81	75	78	74	70	89	101	148	183	271
16	100	123	120	120	49	28	39	162	241	400	505	340
17	78	80	99	88	89	95	107	183	375	541	533	408
18	134	113	119	91	60	41	65	185	311	375	410	374
19	118	117	88	23	21	23	50	139	258	303	224	226
20	73	75	88	99	87	89	120	235	310	334	319	291
21	34	22	22	36	50	56	71	77	192	282	302	310
July 1	13	23	22	18	21	8	18	54	104	152	260	231
2	82	64	47	33	27	22	17	39	168	172	331	340
Means	82	80	79	69	55	47	58	123	225	298	337	310

75th meridian time west in hours												
12–13	13–14	14–15	15–16	16–17	17–18	18–19	19–20	20–21	21–22	22–23	23–24	0–24
306	249	212	199	161	88	63	74	65	60	57	47	136
359	309	220	303	246	179	111	80	70	71	107	128	146
279	239	198	120	44	59	32	63	69	73	73	78	140
371	290	243	176	97	104	107	181	134	118	124	113	197
286	229	174	174	148	73	89	109	99	91	100	105	165
174	129	110	113	110	118	101	103	105	83	80	73	120
180	189	143	117	91	70	47	28	36	39	40	34	131
280	190	133	117	65	104	133	109	70	77	74	77	120
164	212	199	162	128	144	111	89	101	93	93	101	105
364	342	294	293	226	159	99	84	92	87	73	36	145
276	238	193	177	132	110	89	92	84	79	82	79	140

a circular area of 50 feet in diameter around the collector was cleared and leveled.

The following meteorological observations were made: Humidity, using a hair-hygrograph which was in continuous operation; extreme temperatures were read daily from maximum and minimum thermometers; a weather journal was kept which included general weather notes, types of clouds, direction of wind, etc. Dust-count determinations were made with the Aitken dust counter whenever practicable.

Although records were obtained over 23 days at Matahuata and over 29 days at Cerro-de-Ahuac, unusually unfavorable weather rendered many of these days incomplete, and in the tables given below only complete "zero-days," that is, days on which negative potentials were recorded for less than an aggregate of three hours and during which no interpolations were necessary, are included.

The curves reproduced in Figure 2, which are derived from

TABLE 5.—*Hourly values in volts per meter of potential gradient at Huancayo Magnetic Observatory* (values reduced to infinite plane by application of reduction-factor 1.07)

Date 1937	75th meridian time west in hours											
	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12
Jan. 12	21	21	20	22	19	19	25	41	66	88	96	105
14	26	24	21	22	20	21	25	56	95	125	133	112
16	23	21	21	20	[illegible]	22	21	45	87	122	156	124
17	14	12	14	19	17	12	19	74	122	141	143	92
18	11	19	20	21	[illegible]	11	24	59	71	104	113	105
19	21	20	12	25	21	19	22	52	77	95	92	86
20	19	11	11	14	19	21	21	72	83	101	106	105
21	19	22	12	14	21	20	23	52	71	76	79	68
Feb. 1	21	22	23	26	26	20	25	40	62	81	93	88
2	11	28	21	28	12	22	22	43	56	84	73	83
Means	21	21	20	21	20	20	24	52	79	101	109	96

75th meridian time west in hours												
12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	0-24
91	63	77	65	66	55	22	35	34	21	15	22	45
97	93	86	92	68	51	68	47	42	29	31	20	59
77	52	67	46	27	29	16	27	31	25	22	22	46
111	75	62	64	40	42	40	29	45	54	39	26	55
92	66	73	73	62	[illegible]	29	[illegible]	25	17	22	17	46
73	72	75	71	58	44	34	43	45	45	28	20	45
71	[illegible]	33	27	30	31	12	22	12	18	19	19	39
47	51	35	32	27	46	46	35	34	29	35	34	37
96	77	66	67	59	52	35	30	35	35	34	22	47
81	106	106	76	89	42	49	25	24	27	19	16	36
82	69	61	54	47	42	36	32	33	29	26	22	46

the hourly means of Tables 1 to 4, show, as might be expected, that the diurnal variation at the two more elevated stations has the same general characteristics, namely, a single wave with a maximum between 15^h and 16^h G. M. T. This is in general accord with the results of other observers.[2] However, there is a minimum between 10^h and 11^h G. M. T. indicated at Matahuata which is more pronounced at the higher station. In their general aspects the curves display as close an agreement, one with the other, as the distance between the three stations would permit one to expect. The slight irregularities in the curves from the mountain stations following 22^h G. M. T. between 17^h and 20^h, 75th meridian time, can be attributed to electrical storms which invariably occur at this season of the year in the early evening hours. It will be noticed that the curves from the Observatory for the same periods are much less

[2] W. Conrad und F. M. Exner, Registrierungen des luftelektrischen Potentials auf dem Sonnblick. Sitzber. Ak. Wiss. Wien, Math.-Nat. Kl., v. 112, 1903 (413-415).

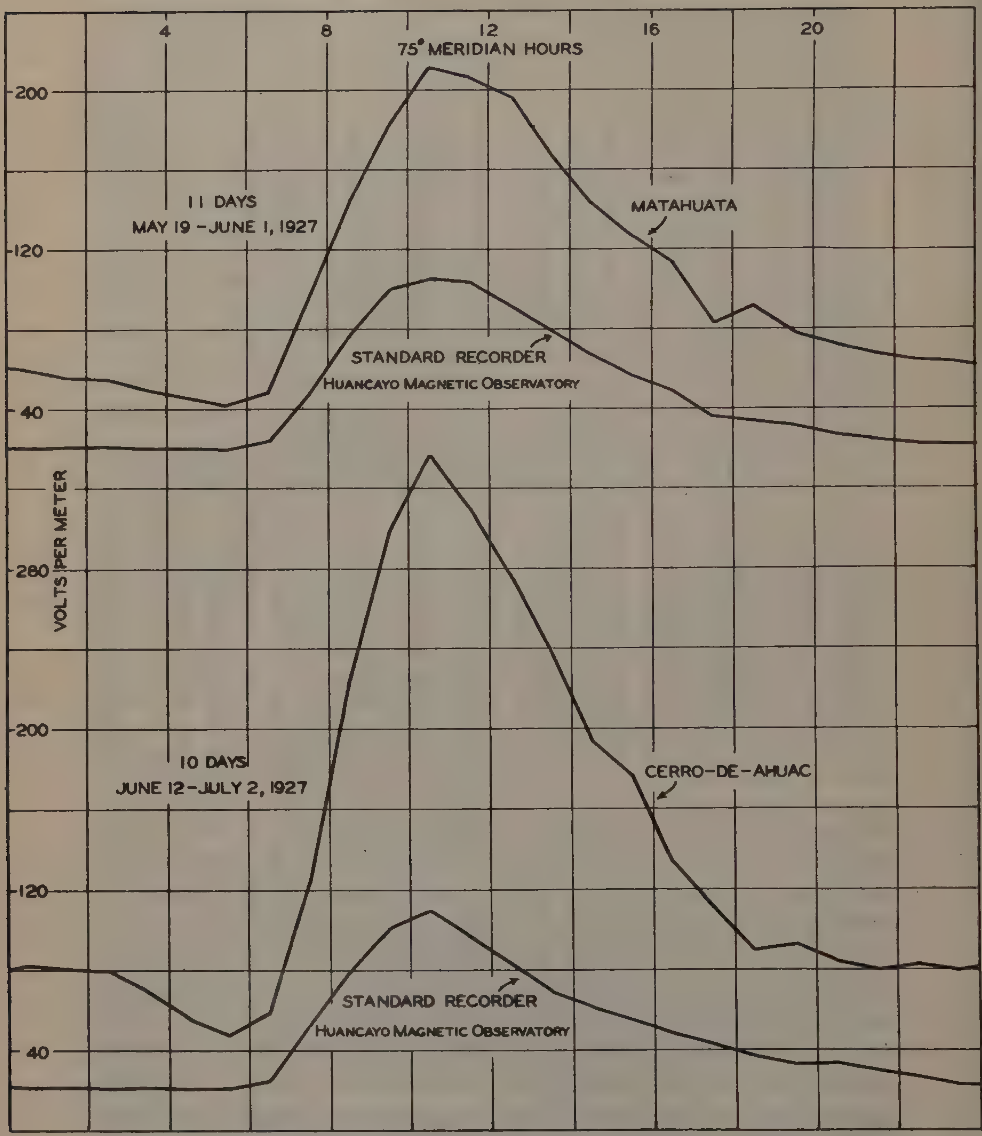

FIG. 2—Diurnal-variation graphs of observed atmospheric-electric potential-gradient for "zero-days" at mountain stations near Huancayo, Peru

disturbed, due to the sheltered position of the Observatory compared with the mountain peaks.

The relative mean potentials obtained at the three stations may be summarized in the following way:

Station	Height above base-station *feet*	Mean potential *v/m*	Relative values
Huancayo Observatory........	00	49	1.00
Matahuata..................	500	102	2.17
Cerro-de-Ahuac...............	2,200	140	3.06

It might have been anticipated, in view of the relative altitudes of Matahuata and Cerro-de-Ahuac above the base-station (1 to 4.4), that the potentials of the latter station should be higher than those actually observed, but the apparent discrepancy is probably due to the difference in contour of the two mountains. Some observations of potential gradient made by the Department of Terrestrial Magnetism during the total solar eclipse of 1918 at Lakin, Kansas (3,000 feet) and also at the summit of Pikes Peak (14,000 feet) show the potentials prevailing at Pikes Peak to be roughly twice those at Lakin. The results obtained at the station on Pikes Peak have not yet been published; those obtained at Lakin have been discussed by S. J. Mauchly and published.[4]

Amplitudes and phase-angles derived from Fourier analyses of the curves are given in Table 5. A summary of the dust-count observations made is given in Table 6; it is to be noted that the values given for visibility are based on an arbitrary scale, namely, 0 for very poor to 3 for perfect visibility.

TABLE 5—*Fourier coefficients of potential-gradient curves from Huancayo Magnetic Observatory and field stations in vicinity*

Station	Date	Amplitudes				Phase-Angles			
		c_1	c_2	c_3	c_4	a_1	a_2	a_3	a_4
	1927	*v/m*	*v/m*	*v/m*	*v/m*	°	°	°	°
Matahuata......	May 19–June 1	67.2	34.1	14	5	255.2	94.7	315	194
Huancayo Obs'y..	May 19–June 1	34.8	15.9	7	4	263.5	110.7	325	202
Cerro-de-Ahuac..	June 12–July 2	104.7	61.4	27	14	262.4	84.3	324	199
Huancayo Obs'y..	June 12–July 2	34.3	16.6	9	5	263.1	115.5	331	198

[4]See *Terr. Mag.*, v. 24, 1919 (22-28 and 87-97).

TABLE 6.—*Dust-count observations made with Aitken dust-counter at Huancayo Magnetic Observatory and vicinity*

Station	Date	75th meridian time	No. of particles per cc	Visibility	Station	Date	75th meridian time	No. of particles per cc	Visibility
	1927	*h m*				*1927*	*h m*		
Matahuata	May 25	11 10	1,680	2	Huancayo Obs'y	June 16	10 15	1,700	2
	25	14 50	640	2		16	14 50	2,600	2
	26	9 40	2,600	2		17	11 10	2,900	2
	26	14 45[a]	970	3		17	14 40	4,700	3
	27	10 30[b]	2,600	2		19	12 00	45,000	1
	27	14 10[c]	2,560	2		19	17 00	1,450	3
	28	9 05[d]	480	2		20	8 15	35,800	1
	28	10 00	2,950	1		20	12 05	22,000	1
	28	10 50[e]	2,520	2		20	16 15	2,050	2
	28	14 10	2,480	3		21	11 35	19,500	2
	28	14 55	2,560	3		21	16 05	5,400	3
	28	15 50	2,620	3		22	10 45	42,400	3
	30	10 45	49,500	1		22	11 00[i]	148,000	2
	30	14 30	28,500	2		22	11 45[i]	69,500	2
						22	15 40	53,000	2
Huancayo Obs'y	May 30	11 45	55,000	1		23	9 15	86,500	2
						23	9 55	75,000	2
Cerro-de-Ahuac	June 5	14 00[f]	1,530	1		23	10 25	47,500	2
	6	15 57	2,410	2		23	10 53	96,500	2
	7	10 40	3,400	1		23	11 27	84,000	2
	7	14 35	3,860	1		23	11 55	47,500	2
	7	15 13	3,000	1		23	12 50	41,500	2
	8	10 10	2,400	2		23	13 25	43,000	2
	8	11 48	3,630	2		23	13 55	34,500	2
	8	14 05	950	3		23	14 30	41,000	2
	9	9 37	2,450	2		23	15 00	41,500	2
	9	11 50	950	2		23	15 30	48,500	2
	9	15 00	3,600	2		23	16 00	20,500	2
	10	9 55[g]	6,200	1		23	16 30	9,000	2
	11	10 55[h]	3,450	1		23	17 00	700	2
	12	10 15	1,246	1					

[a]Thunderstorm to north (8 to 10 miles). [b]Rain to north (12 miles), thunder in west (10 miles). [c]Rain early a.m. [d]Hazy to north. [e]Hazy to north; calm. [f]Calm; low clouds clearing from west. [g]Low cumulus (10 –). [h]Low belt of haze. [i]Observations made by different observers.

In view of the advantage of having a base-station for control, as at the Huancayo Observatory, it is hoped that at some future time it will be possible to make some further observations at both Matahuata and Cerro-de-Ahuac covering a longer period of time in order to obtain some data on seasonal variations.

Grateful acknowledgment is made of assistance received during the prosecution of this work from J. A. Fleming, Assistant Director of the Department of Terrestrial Magnetism, from R. H. Goddard and O. W. Torreson, observers-in-charge of the Observatory, and for valuable suggestions during the discussion of the data from S. J. Mauchly and O. H. Gish.

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NOTE ON SOME PHOTOGRAPHS OF LIGHTNING-DISCHARGES MADE AT THE HUANCAYO MAGNETIC OBSERVATORY

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Abstract—The photography of lightning-discharges affords valuable data for the solution of some fundamental problems in atmospheric electricity. In this note description is given of the methods used to obtain photographs on motion-picture film of lightning flashes at Huancayo, a location very suitable for this work. Specimen photographs are given and briefly discussed and the necessity for further work indicated.

The importance of the study of lightning-discharges in their relation to fundamental problems of atmospheric electricity has, in recent years, become increasingly recognized. The quantitative experiments of C. T. R. Wilson[1] and the theoretical studies of Simpson[2] and others point to the necessity for obtaining further observational data at stations over the Earth's surface and under varying conditions.

Much valuable information may be obtained from the study of photographs of lightning-flashes and the present note describes an initial attempt to secure such photographs during thunderstorms at the Huancayo Magnetic Observatory. This Observatory is located some 120 miles east of Lima, Peru, at an elevation of 11,000 feet above sea-level. From many points of view, it is favorably situated for this work; thunderstorms are of frequent occurrence and, in general, follow well defined paths; also, except to the south, the sky-line is not unduly elevated.

During a storm on March 29, 1927, which commenced at about 17^{h} (75th meridian time) and lasted until nearly 20^{h}, about 40 exposures were made between $18^{h}40^{m}$ and $19^{h}30^{m}$. Of these, 30 exposures showed flashes sufficiently well to justify printing.

The apparatus used was a Sept motion-picture camera which, besides the advantages of economy, is very suitable for this work owing to the ease and rapidity with which the film can be changed after each flash has recorded itself. The camera, of course, is used as a still camera, with the shutter held open as for a time-exposure. Raising and depressing the shutter-key changes the film one frame and, as this operation can be performed in less than one second, there is much less danger of a discharge being missed than when using an ordinary camera. The camera is mounted on a rigid tripod and, to minimize the danger of rain striking the lens, enclosed in a box which is fitted with suitable apertures for sighting through the direct-vision view-finder and for manipulating the shutter-key.

At $18^{h}40^{m}$ the center of the storm bore north by west from the point of observation and was distant roughly eight miles. At the

[1] C. T. R. Wilson, Investigation on lightning discharges and on the electric field of thunderstorms. *Phil. Trans. R. Soc., A*, v. 221, 1920 (73-115).

[2] G. C. Simpson, On lightning. *Proc. R. Soc. A*, v. 111, 1916 (56-67).

nearest point it bore north-northeast and was distant three to six miles. As far as can be judged, the storm progressed in a line bearing slightly south of east. Its maximum intensity appeared to be at about $18^{h}30^{m}$ or just before the sky was dark enough to commence photography.

Examination of the 30 photographs obtained, using the classification adopted by Simpson in the paper quoted above and with the same reservations, gives: Class I, 10; Class II, 0; Class III, 16; Class IV, 2; and Class V, 5. The last class was added to include those photographs which show multiple flashes (see Fig. 5).

The photographic record of potential gradient obtained at the Observatory during the storm was, of course, highly disturbed. Close examination shows that between 17^{h} and 18^{h} the air-potentials were high positive; from 18^{h} to 19^{h} some periods of high neg-

Figs. 1 to 6—Specimen photographs of lightning-discharges, March 29, 1927, at the Huancayo Magnetic Observatory

ative air-potentials were shown but it is impossible to say whether this condition persisted during the whole hour; between 19^h and 20^h high positive potentials were indicated, and after 20^h the trace quickly descended to its normal positive value.

Figures 1 to 6 are reproductions from enlargements of the original motion-picture negatives. These enlargements may be readily made by passing the negative through the Sept camera and having a source of light behind the film with a projecting screen at a suitable distance in front of the lens. The photographs are numbered in the order of their exposure. No. 1 was taken at about 18^h40^m. In Nos. 3 and 4 a portion of the main path of the discharge is in duplicate; such an effect could be produced by double exposure or shift of camera but, as the phenomenon is confined to a small portion of the visible flash, this explanation is not very probable. No. 5 shows what is undoubtedly a multiple flash; it is hardly possible that there was enough motion of the camera in azimuth to produce from an undivided flash the result shown. The horizontal bar above the sky-line shown in photographs Nos. 5 and 6 is the top rail of a tennis back-stop, about 70 feet from the point of observation.

It is hoped to continue this work of lightning photography, as opportunity offers, at Huancayo and to secure such control observations as will give a maximum amount of information from the photographs secured.

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NOTES

(See also page 58)

1. *Isogonic Chart, Belgian Congo and French Equatorial Africa.*—In *Ciel et Terre* for December 1927, Dr. Edm. Lahaye has published an isogonic chart (epoch January 1, 1927) of Belgian Congo and French Equatorial Africa primarily for the use of aviators as based largely on the values published in the "Researches of the Department of Terrestrial Magnetism." The chart discloses an important anomaly between 0° to 5° north and 10° to 20° east, and another, of less intensity, between 5° to 10° south and 20° to 25° west. The author emphasizes that in vast territories where no magnetic observatories exist the secular variation cannot be determined with precision unless the programs of large magnetic expeditions include continuous registrations extending over one or more days at intervals of four or five years and at a sufficient number of stations.

2. *The Slutzk (Pavlovsk) Observatory.*—The Slutzk (Pavlovsk) Magnetic and Meteorological Observatory celebrated on December 4, 1927, the fiftieth anniversary of its foundation. This Observatory, well equipped with magnetic instruments designed by its first director, H. Wild, was for many years the most northern observatory in the world and has supplied a long series of magnetic results of great value to research workers. Observations in atmospheric electricity were begun in 1913.

3. *Potsdam Magnetic Observatory.*—The report of the Prussian Meteorological

Institute for the year 1927 states that imminent electrification of the suburban railway passing in the vicinity of the Potsdam Observatory will soon render absolute magnetic observations there impossible as well as the continuous registration of the magnetic elements at the auxiliary station, Seddin. Accordingly, the Observatory must be transferred to a new locality in the near future; several new sites have already been considered, but at the end of 1927 no definite choice had been made.

4. *Geophysical Applications.*—Two sessions on February 20, 1928, of the 136th meeting of the American Institute of Mining and Metallurgical Engineers held in New York City were devoted to geophysical methods of prospecting. The program included papers and discussion on (1) gravity methods and (2) electrical and magnetic methods. Some of the papers were: Geophysical exploration for ores, by Max Mason; Remarks on magnetic method of survey, by L. B. Slichter; Certain applications of the surface potential method, by Warren Weaver; Recent results in electrical prospecting for ore, by Hans Lundberg; Earth-resistivity measurements in the Lake Superior Copper Country, by W. J. Rooney, W. O. Hotchkiss, and James Fisher; A new micro-magnetometer, by Frank Rieber; Working method of practical geophysics, by Hans Haalck; and Radiore methods, by Edward H. Guilford.

The program for the ninth annual meeting of the American Geophysical Union to be held in Washington on April 26 and 27, 1928, includes on April 26 a symposium and discussion on "Geophysical methods as applied in the study of geological structure" before a joint meeting of the Sections of Terrestrial Magnetism and Electricity, Seismology, and Geodesy. The papers in this symposium are: The relation of the magnetic work of the U. S. Coast and Geodetic Survey to geophysical prospecting, by D. L. Hazard; Geophysical prospecting methods with special reference to magnetic, radioactive, and electric methods, by C. A. Heiland; Depths of ground-water and some geological structure indicated by earth-resistivity surveys, by O. H. Gish; Mapping geological structure with the Eötvös torsion balance, by Donald C. Barton; Transmission of elastic waves through surface rocks; The advance of an earthquake disturbance, by H. F. Reid.

5. *German Geophysical Society.*—The sixth meeting of the Deutsche Geophysikalische Gesellschaft was held at Frankfurt a.M. on September 26-28, 1927. Among the papers presented were the following: Schlomka, Zur physikalischen Theorie des Erdmagnetismus; Nippoldt, Vorlegung seiner neuen Karte der Anomalien der magnetischen Vertikalintensität in Europa; Wehner, Säkularvariation des Erdmagnetismus und Kunstgeschichte. The following officers were elected: President, E. Kohlschütter, Potsdam; Vice-Presidents, O. Hecker, Jena, and L. Weickmann, Leipzig; Treasurer, W. Schütt, Hamburg; Editor of *Zeitschrift für Geophysik*, G. Angenheister, Potsdam. The Society will meet next year at Hamburg at a date not yet fixed.

6. *Fourth Pacific Science Congress.*—The Fourth Pacific Science Congress will be held at Batavia, Buitenzorg, and Bandoeng, Java, during May and June 1929 under the auspices of the Pacific Science Association. The General President of the Congress and Chairman of the Netherlands Indies Pacific Research Committee is Dr. A. A. L. Rutgers.

7. *International Scientific Meetings.*—During the year 1928, the following international scientific meetings will be held in Europe: International Astronomical Union, Leiden, July 5; International Research Council, Brussels, July 10; International Mathematical Union, Bologna, September.

SUMMARY OF MAGNETIC-SURVEY WORK BY THE CARNEGIE INSTITUTION OF WASHINGTON, 1905-1926

By J. A. Fleming and H. W. Fisk

The general magnetic survey of the globe, to the accomplishment of which the Carnegie Institution of Washington, through its Department of Terrestrial Magnetism under the energetic guidance of Director Louis A. Bauer, devoted its energies for many years, has been completed for the major part of the Earth.[1] While this task has been accomplished through the labors of the Department, these were directed chiefly to the ocean areas and to those countries or regions for which magnetic data would not otherwise be obtained promptly. In some regions, required magnetic surveys were accomplished by cooperation with existing organizations or with interested investigators. Valuable data in polar regions have been obtained by successful cooperation with the Peary Arctic Expedition, the Mawson Antarctic Expedition, the Amundsen Arctic expeditions, and the Baffin Land and North Greenland expeditions of Dr. Donald B. MacMillan.

With the general magnetic survey to a large extent accomplished, it has become possible to devote a larger proportion of the available resources to the study of other pressing problems. Accordingly, in the future, fewer expeditions will be sent out and the chief emphasis will be placed on problems pertaining to secular and diurnal variations in regions remote from magnetic observatories.

During the last decade the observers of the Department have for the most part been concerned with securing secular-variation data by the reoccupation of magnetic stations established by previous observers. It has been found practicable also to visit a few regions not hitherto reached in a course of earlier surveys, for example, certain portions of the interior of Brazil, the island of Madagascar, the Bahama Islands, and regions covered by arctic expeditions. Thus, at the end of 1926, repeat stations fairly well distributed for purposes of secular-variation discussion had been occupied in the general region of the South Pacific, in Australia and New Zealand, over all of Central America and South America, throughout the West Indies, and in parts of Africa including Morocco, West Africa from the mouth of the Niger to Lake Tchad, and portions of East Africa.

[1] The results thus far obtained and including the period 1905 to 1926 have been published by the Carnegie Institution of Washington as its Publication No. 175; thus far six volumes have appeared, the last having been issued in October 1927.

A general idea of the extent of the operations of the Department and an indication approximately of the density of distribution of the places at which observations have been made in the several regions are given in Table 1.

Table 1—*Summary of land operations of the Carnegie Institution of Washington through its Department of Terrestrial Magnetism, 1905 to 1926*

Geographical divisions	Stations enumerated				Totals 1905 to 1926	
	Volume				Stations	Expe-ditions[a]
	I 1905–1910	II 1911–1913	IV 1914–1920	VI 1921–1926		
Africa	389	191	481	113	1,174	22
Asia[b]	323	82	[c]405	[d]353	1,163	23
Australasia	11	284	336	117	748	23
Europe	42	36	32	24	134	5
North America	368	50	139	202	759	43
South America	115	248	369	240	972	27
Islands:						
Atlantic	77	16	20	203	316	12
Indian	1	14	33	71	119	3
Mediterranean	2	2	...	4	8	3
Pacific	64	16	106	75	261	12
Antarctic Regions	...	31	...	...	31	1
Totals	1,392	970	1,921	1,402	5,685	174

[a]Including expeditions engaged in minor operations and special work.
[b]Including stations occupied by the *Maud* in the Arctic Sea off the coast of Siberia.
[c]Including 41 stations occupied by the *Maud* during 1918 to 1920 but published in Volume IV.
[d]Not including 41 stations published in volume VI which were occupied during 1918 to 1920; see preceding footnote.

Table 2 summarizes all the Department's land results for the past 22 years by geographical divisions, including station-occupations and number of repeat localities and repeat occupations.

The number of secondary and auxiliary stations for Asia is appreciably increased by the inclusion of a large number established on the ice of Arctic Ocean north of Siberia during the drift of the *Maud*, 1922-1925. Although made over the ocean, the instruments used and the methods of observing were the same as those employed at land stations, so that they are appropriately published in the list of land magnetic results. Although the motion of the ice with which the *Maud* was drifting was so slow as to produce no interference with the observations, it was sufficient to require a change in the geographic coordinates by which the station was described. This irregular day-to-day motion was so small that a great many stations are found grouped about within a comparatively small area, so that they are better regarded as auxiliary stations than as separate

FIG. 1—Magnetic survey-work of the Carnegie Institution of Washington during 1905-1926
(Cruises of the *Galilee* are indicated by Arabic numbers, those of the *Carnegie* by Roman numerals; black dots show the land stations)

primary stations. In a somewhat similar way the number of secondary stations in the Islands Atlantic Ocean group has been increased by counting a large number of stations in Bermuda made for the purpose of investigating the magnetic anomaly existing there.

TABLE 2—*Summary of land operations showing details of station-occupations and of repeat-localities, 1905 to 1926*

Geographical divisions	Station-occupations			Repeat-localities	
	Primary	Auxiliary	Secondary	Number	Occupations
Africa	1083	78	13	113	253
Asia[a]	782	130	251	64	163
Australasia	613	57	78	96	250
Europe	94	31	9	14	39
North America	600	127	32	79	217
South America	823	117	32	112	304
Islands:					
Atlantic	154	115	47	30	79
Indian	94	16	9	4	11
Mediterranean	8	0	0	3	6
Pacific	188	48	25	44	109
Antarctic regions	25	1	5	2	4
Totals	4,464	720	501	561	1,435
Total station-occupations					5,685

[a]Including stations occupied by the *Maud* in the Arctic Sea off the coast of Siberia.

The ocean work of the Department was initiated in 1905. The early work in the Pacific Ocean during 1905 to 1908 was carried out on the chartered brigantine *Galilee*. In 1909 a specially designed non-magnetic vessel, the *Carnegie*, was built, and all the work at sea since that time has been done with this vessel excepting a special expedition into Hudson Bay in 1919 on a chartered schooner. The summary of ocean magnetic work of the *Galilee* and the *Carnegie* during 1905 to 1921 as given in Table 3 (see also Fig. 1) shows the total number of observed values of declination to be over 3,300, and of inclination and horizontal intensity to be over 2,100, the stations being distributed in the Pacific, Atlantic, and Indian oceans in the proportion of about 4, 2, and 1, respectively. While the oceans have now been quite thoroughly traversed between parallels 60° north and 60° south, there still remain areas of 500,000 square miles or more in extent, especially in the Pacific Ocean, within which no magnetic observations have been made.

The results of the ocean work have been incorporated in the isomagnetic charts of the leading hydrographic offices, and chart-errors, which reached an appreciable magnitude in 1905, are now

TABLE 3—*Summary of magnetic work at sea by the Galilee and the Carnegie during eight cruises in 1905-1921*

Ocean and approximate epochs of observation	No. of nautical miles	No. of obs'd values		Cruise intersections used for annual-change data	Square statute miles per station	
		Declination	Inclination and hor. int.		Declination	Inclination and hor. int.
Pacific: 1905-08, 1912, 1915-16, 1921	181,423	1,800	1,183	47	35,600	53,700
Atlantic: North, 1909-10, 1913-14, 1919; South, 1910-13, 1920	92,053	1,039	682	27	30,300	46,300
Indian: 1911, 1920	43,060	477	282	7	59,100	49,800
Total........	316,536	3,316	2,147	81	37,300	57,500

within limits sufficient for all economic purposes and to a large degree for general magnetic investigations. Such as do exist may usually be attributed to imperfect knowledge of the secular changes which are more complicated even over the deep sea than was supposed to be the case.

A comprehensive exhibit of the general uniformity of distribution of the repeat-localities is presented by the equal-area map in Figure 2[1] upon which the total numbers of repeat-stations for areas of convenient size are represented by numbers within circles (the numbers within the squares are the corresponding numbers of secular-variation positions derived from the ocean surveys). Anything approaching a uniform network of stations over the entire surface of the Earth is impossible under present-day conditions. The same is true of the repeat-localities, though conditions for these are better because of their wider separation. The distribution, except for the polar regions where for obvious reasons few observations have been made and for Asiatic Russia, while by no means uniform, is nevertheless fairly well spread over the whole surface.

A summary showing the totals of repeat-localities as distributed in the arbitrary divisions indicated by the heavy lines in Figure 2 is given in Table 4.

Of the improvements in instruments, particularly as regards compactness and portability, made in the Department's own shop as the work progressed, probably the most important was that of the design of an earth inductor and galvanometer by which

[1]The base used for this figure is the "homolosine equal-area projection" prepared by Professor J. Paul Goode, copyright by the University of Chicago and used with permission.

Table 4—*Summary to show regional distribution of secular-variation magnetic data obtained by the Department of Terrestrial Magnetism of the Carnegie Institution of Washington through 1926, arranged according to arbitrary geographical divisions indicated on Figure 2*

Geographical division	Region or country	No. secular-variation localities
1	Alaska, Western Canada.	5
2	Greenland	5
3	Eastern Canada 16	
	Newfoundland and Labrador 7	23
4	Western United States . .	5
5	Eastern United States. . .	8
6	Bermuda	5
7	Mexico	7
8	Central America. 26	
	West Indies (West) . . . 7	33
9	West Indies (East)	13
10	Colombia 9	
	Ecuador 4	
	Venezuela 9	
	Guiana 9	31
11	Peru 21	
	Bolivia 4	
	Brazil (West) 5	30
12	Brazil (East)	17
13	Chile 14	
	Argentina 17	
	Paraguay 2	
	Uruguay 1	34
14	Falkland Islands	1
15	Hawaiian Islands 1	
	Fanning Island 1	2
16	Cook Islands 1	
	Samoan Islands 3	
	Society Islands 1	
	Tokelau Islands 3	
	Tonga Islands 2	10
17	Cape Verde Islands	0
18	Madeira Islands 1	
	Canary Islands 2	3
19	Europe (West)	12
20	Europe (East), Batum and Tiflis	2
21	Mediterranean	3
22	Asia Minor 11	
	Arabia 2	13
23	Morocco 5	
	Algeria 2	
	Algerian Sahara 1	
	Tunisia 2	
	Tripolitania 1	11
24	West Africa 22	
	Gambia 1	
	Gold Coast 3	
	Sierra Leone 3	
	Liberia 3	32
25	Nigeria 8	
	French Equatorial Africa 4	
	Cameroun 3	15
26	Egypt 4	
	Sudan 1	
	Abyssinia 3	
	Eritrea 2	
	Somaliland 1	11
27	Belgian Congo 8	
	Angola 9	17
28	Uganda 2	
	Kenya Colony 6	
	Tanganyika 4	12
29	St. Helena Island	1
30	Southwest Africa 6	
	British South and Central Africa 6	
	Portuguese East Africa . . . 3	15
31	Zanzibar 1	
	Madagascar 1	2
32	North Siberia	6
33	South Siberia	0
34	India	2
35	North China	13
36	Middle China	20
37	South China 5	
	Indo-China 3	
	Straits Settlements 1	9
38	Japan	1
39	Marshall Islands 1	
	Marianas 1	2
40	East Indies (Java)	1
41	Western Australia	24
42	Northern Territory	6
43	Queensland	21
44	South Australia, New South Wales, Victoria, and Tasmania	36
45	New Zealand 9	
	Lord Howe Island 1	10
46	Bismarck Archipelago 1	
	Ellice Islands 8	
	Fiji Islands 1	
	New Caledonia and Loyalty Islands 5	
	New Guinea 6	
	New Hebrides 1	
	Solomon Islands 7	29
47	Antarctic	2
48	Ceylon	1
	Grand total	561

FIG. 2—Regional distribution of magnetic secular-variation data through 1926, obtained by the Carnegie Institution of Washington
(Numbers in circles apply for land work and in squares for sea work; base map is that of J. Paul Goode, copyright by the University of Chicago Press)

the dip circle has been quite generally superseded by the earth inductor as an inclinometer. The dip circle has been retained, however, as the most practicable instrument for use in the polar regions, not only for the determination of inclination but for intensity as well by the Lloyd total-intensity method. The practice of determining corrections on the adopted provisional International Magnetic Standards of the Department has been developed by intercomparisons of instruments at observatories in all parts of the world and by comparisons with standard instruments at Washington. The corrections for the field instruments have been derived from direct comparisons with the standard instruments. This method has the advantage of simplicity and insures a greater homogeneity of results where the observations have been made by different observers using different instruments. For some of the instruments these repeated comparisons showed a progressive increase with time in the amount of the correction for horizontal-intensity results. This correction has been found to arise from a change in the moment of inertia of the long magnet used in oscillations, caused by a slow wearing away of the gold-plating with which the brass sheaths of the magnets are covered. The introduction of a linear time-factor in the expression of the correction has been found to harmonize the results satisfactorily. The corrections to observed results for declination with the magnetometer and for inclination with the earth inductor have been uniformly small and do not seem to require any change for differences of declination or of inclination in the regions visited throughout the northern and southern hemispheres.

It has long been the practice of observers of the Department to make daily runs at occasional stations of eye-readings for declination, these continuing over 10 hours or more, to determine the diurnal variation for the day and place. Beginning in 1922, after the adoption of the earth inductor as a field instrument, the practice was inaugurated of making observations for inclination at intervals of 20 minutes throughout the day. By modifying the method of making observations in declination, by determining the magnetic meridian from deflections, and placing the deflecting magnet in its four positions at one distance only, there may be obtained at the same time a series of angles from which the horizontal intensity may be computed. Thus for many stations a single day's specimen curve of diurnal variation in all three elements has been secured in the course of the field work, although the design of the instrument has not permitted the determination of all three on the same day. The details of these diurnal-variation observations are

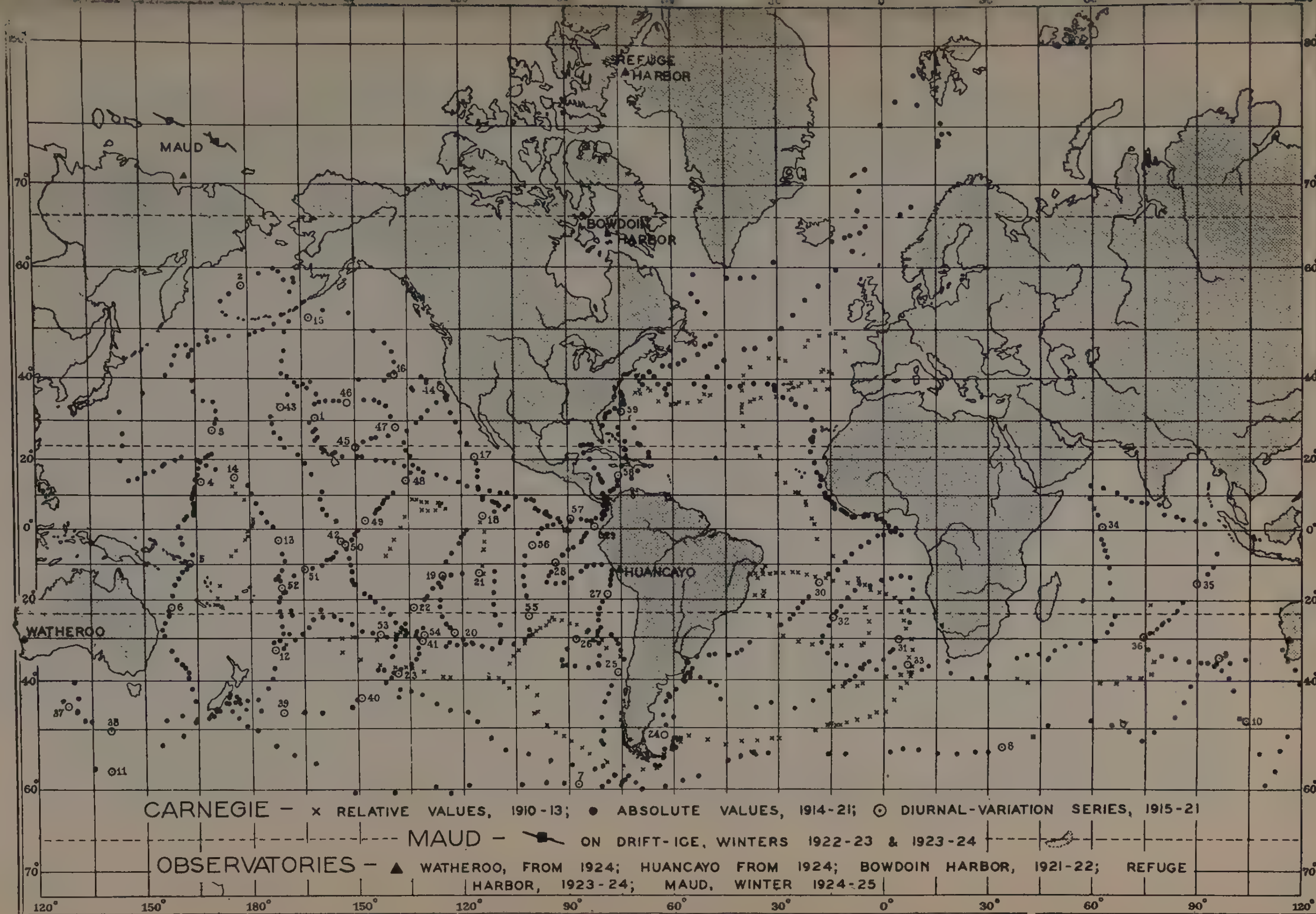

FIG. 3—Electric survey-work of the Carnegie Institution of Washington during 1910-1926
(Distribution of atmospheric potential-gradient stations of the *Carnegie*, of the *Maud*, and at observatories)

not yet published as a discussion can be more advantageously made when the results from observatories for the same days are available. The results obtained have served to emphasize the great desirability of designing a really portable and accurate field instrument capable of automatically registering magnetic variations over periods of from a few days to a week at field stations; such equipment would greatly aid in the accumulation of data for the study of the space distribution of the magnetic diurnal ranges.

During the earlier work of the *Carnegie*, atmospheric-electric observations were made at sea primarily to develop methods and appliances for the determination of electric distribution. Much of this preliminary work gave relative values only, but as the result of this work and of experimental work in the laboratory it was possible, beginning in March, 1915, with the fourth cruise of the vessel, to make systematic absolute determinations of the atmospheric-electric elements at sea.

The atmospheric-electric results at sea from 1915 to 1921 include potential gradient (see Fig. 3), negative and positive ionic content, conductivity, and ionic mobility, penetrating radiation, and radioactive content, together with accompanying detailed meteorological data. They are summarized in Table 5 for 955 stations in all

TABLE 5—*Atmospheric-electric stations at sea and diurnal-variation series during cruises of the Carnegie, 1915-1921, for one or more elements and series of four hours or more*

Cruise	Ocean							
	Atlantic		Pacific		Indian		Southern	
	No. of stations	No. of D.V. series	No. of stations	No. of D.V. series	No. of stations	No. of D.V. series	No. of stations	No. of D.V. series
IV	22	1	293	27	...	..	76	14
V	38	2	66	7	...	..	..	..
VI	164	8	178	27	118	10	..	..
Totals...	224	11	537	61	118	10	76	14

Total for all oceans 1915-1921: stations, 955; diurnal-variation series, 96

oceans at which one or more elements were observed and for 96 series for diurnal variation of one or more elements including four hours or more of observation.

DEPARTMENT OF TERRESTRIAL MAGNETISM,
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THE MAGNETIC AND ELECTRIC OBSERVATIONS OF THE *MAUD* EXPEDITION DURING 1918 TO 1925

By H. W. Fisk and J. A. Fleming

It is well recognized that the accumulation of additional reliable data in terrestrial magnetism and electricity in the polar regions is of first importance to the definite solution of unsolved problems both from the statistical and laboratory method of approach. The increased world-wide interest in polar exploration evidenced, for example, by the rapidly-developing plans of the International Society for the Exploration of the Arctic by Means of the Airship (Aeroarctic) and of the Byrd Antarctic Expedition, besides the already growing importance of establishing air-routes in these regions, emphasizes the value of intensive scientific effort.

The possibilities of obtaining valuable data on polar expeditions despite the unusual and extreme conditions encountered as well as the handicap of limited personnel are well illustrated by the recently published admirable reports[1] on the magnetic and electric observations of the *Maud* Expedition in the second part of Volume VI of the "Researches of the Department of Terrestrial Magnetism." These reports give the results and discussion of the data obtained through cooperation of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington with the *Maud* Expedition, organized and directed by Captain Roald Amundsen. The scientific work was in charge of Dr. H. U. Sverdrup throughout. Because of the interest of the results to the readers of the Journal it is thought desirable to summarize briefly the operations of the Expedition.

The *Maud* left Vardö, Norway, July 18, 1918, having a total personnel of ten men, with the intention of sailing eastward along the north coast of Russia and Siberia to about 165° east longitude, then pushing northward into the ice as far as possible, and drifting with it across the north pole into the Atlantic, near Greenland. Progress was completely stopped September 13, 1918, just east of Cape Chelyuskin, in east longitude, 105°40′, where the party was detained a full year. The ice conditions were unusually difficult so that attempts to force the vessel northward to the east of the New Siberian Islands were unsuccessful, and the second winter was spent at Ayon Island, in east longitude 167°52′. The winter-quarters here were left July 6, 1920, and Nome, Alaska, was reached three weeks later. A third attempt to penetrate the fields of drifting ice far enough to travel with it as desired, was quickly stopped and winter-quarters were established at Cape Serdze Kamen only 70 miles west of Bering Strait; in this attempt the propeller was damaged

[1] H. U. Sverdrup, Magnetic, atmospheric-electric, and auroral results, *Maud* expedition, 1918-1925. Washington, Carnegie Inst., Pub. 175, vol. 6, 1927 (309-524 with 13 plates and 39 text-figures).

so that in the summer of 1921 it was necessary to proceed to Seattle for repairs.

What may be termed the second half of the Expedition (1922 to 1925) was under the command of Captain Oscar Wisting, Captain Amundsen not being among the company of eight men who constituted the party, as he had taken up plans for the air-flight across the Polar Basin realized later in the *Norge*. The endeavor to enter the ice-fields was successful and the *Maud* was frozen in August 8, 1922, just east of Wrangell Island. Adverse winds carried the floe toward the Siberian coast so far that, instead of crossing the track of the *Jeannette* to the north of De Long Islands, the vessel was released from the ice August 9, 1924, in latitude 76°15′ north and longitude 143°12′ east, near the point where the *Fram* was closed in during 1893; had the Expedition remained there it might have repeated the course of the *Fram*. However, in obedience to instructions from Captain Amundsen to return if possible through Bering Strait, winter-quarters were established near Four Pillar Island of the Bear Islands in longitude 162°25′ east, a comparatively short distance west of the quarters for the winter 1919 to 1920, five years before. The ice broke around the *Maud* July 13, 1925, and on August 22 the Expedition was terminated at Nome, Alaska, after seven years of effort and six winters in the arctic ice.

While wintering at Cape Chelyuskin, sledge-trips for magnetic observations and other studies were made. During the winter at Ayon Island, Dr. Sverdrup spent over seven months traveling with the native Chukchi, making ethnological studies, and magnetic observations as opportunity offered. In the winter of 1921 to 1922, Captain Wisting and Dr. Sverdrup made a sledge-trip of about 1,200 miles around the Chukotsk Peninsula to Holy Cross Bay; this trip took 69 days, on 23 of which travel was prevented by the frequent blizzards. During the second part of the Expedition no sledge-trips were undertaken and more systematic work was possible in magnetic, electric, and auroral observations.

The Expedition was particularly fruitful in results in terrestrial magnetism, and the allied phenomena of atmospheric electricty and the aurora to which Dr. Sverdrup's reports are chiefly confined.

The instruments used for the magnetic work did not differ essentially from those used for ordinary land observations, the principal modifications being such as experience had shown to be helpful in working at low temperatures. The magnetometer provided by the Department of Terrestrial Magnetism was used chiefly at base-stations, at winter-quarters, and occasionally during the drift for controlling the constants of the dip circle, which was generally depended on for determination of intensity. As the plans for the Expedition were made in the expectation that the vessel would be in constant though irregular motion while drifting slowly with the ice-fields, no provision was made for setting up a temporary observatory. However, a photographic registering declinometer

was operated at Cape Chelyuskin from October 3, 1918, to August 9, 1919, and at Four Pillar Island from December 1, 1924, to May 18, 1925.

The observations made on the sledge-journeys, in the vicinity of Cape Chelyuskin, Ayon Island, and around the Chukotsk Peninsula, combined with the systematic observations maintained for two years on the ice during the drift from east of Wrangell Island to a point north of the New Siberian Islands are of particular interest. When frozen fast in the ice during the drift especial precaution was taken to secure good determinations of the true meridian which were usually done by simultaneous observations by two observers, one using the theodolite and the other using the magnetometer. Geographic position was carefully determined by frequent solar observations and radio time-signals.

The photographic records of declination are discussed quite extensively and conclusions drawn, a few of which may be briefly stated. At Cape Chelyuskin, the declination had the greatest east value on days which were most disturbed and the smallest on quiet days. There was a rapid increase (east) of declination to a maximum at 6^h (L. M. T.), a rapid decrease to 11^h, a more gradual decrease to the minimum at about 22^h at all seasons. The harmonic analysis shows the amplitudes of all terms to increase with disturbance (character-number) but the phase-angles to remain practically constant. The night hours 18^h to 10^h were the most disturbed, while the hours 10^h to 18^h were most quiet. At Four Pillar Island the series was much shorter and conclusions were reached with less confidence. The grouping of days according to mean character fails to reveal any consistent difference between the mean value of declination for disturbed and undisturbed days. The daily curve showed two maxima and two minima. The principal eastern elongation was at about 6^h (L. M. T.) and the secondary about nine hours earlier at 21^h; the primary western elongation was very marked at about 14^h, while the secondary was less pronounced at a little after midnight. The diurnal variation was practically the same for quiet and for moderately-disturbed days (character 0 and 1). For very disturbed days (character 2), the secondary maximum and minimum were so strongly developed that they almost equaled the primary, and the range was very great compared to that of quiet days.

Some striking differences appear in comparing the daily curves for the two places. At Cape Chelyuskin the range was less than 1° in only 2.8 per cent of all cases, while at Four Pillar Island it was less than 30′ in 59 per cent of all cases and greater than 1° in but 16 per cent. At Cape Chelyuskin on the other hand the range was greater than 10° in 10.8 per cent of the cases. The mean absolute range at Four Pillar Island for the months December to May was 37′.5; for the same months at Cape Chelyuskin, it was 5°35′.5 A part of this great difference was no doubt owing to a difference in year with reference to the sunspot-cycle, the mean numbers being

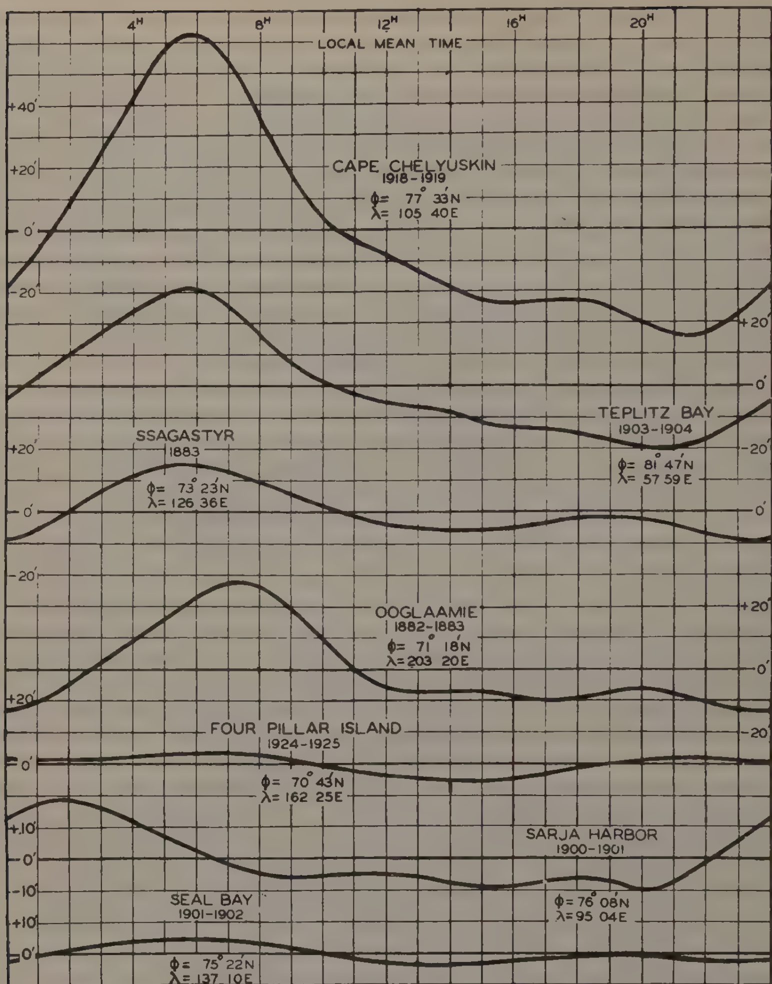

Fig. 1—Diurnal variation of magnetic declination at some arctic stations

23.0 at Four Pillar Island and 66.6 at Chelyuskin. By comparison of all results available at polar stations (see Fig. 1), the conclusion is reached that there is a region in northeastern Siberia where the diurnal range of declination is much less than might be expected according to general theory.

By comparison with results of the *Vega* (Nordenskiöld) expedition of 1878 to 1879, and the Nansen expedition of 1893, some values of the secular change were obtained along the coast. The intervals are too great to determine the present rates of change, as no account

can be taken of accelerations. An indication of these accelerations in the case of horizontal intensity is furnished at Khabarowa (longitude 60°24′ east) where the mean annual change for 40 years, 1878 to 1918 was 16γ a year descreasing, but from 1878 to 1893 was 7γ and from 1893 to 1918, 21γ. A little farther east at Port Dickson, the mean annual rate for the 40-year period was 13γ, while along the north-eastern coast of Siberia it showed a small positive value, namely, 2γ at Konyam Bay in longitude 187°03′ east. In the same distance the mean annual change of declination varied from 4′.2 east at Khabarowa to 6′.6 west at Pitlekai. The annual decrease in inclination was small except at Khabarowa where the inclination increased 59′ in the 25 years from 1893 to 1918.

By comparison of the results of the second part of the Expedition with some results recently published by the Commission for the Exploration of the Republic Yakutsk, the mean secular variation of the declination was determined within two regions, namely, the New Siberian Islands and the coast between Ayon Island and the Kolyma River. Here again the time-interval is too great to provide reliable information as to present conditions. For the 90 years from 1822 to 1912 a mean annual change of 8′.1 west is found for the New Siberian Islands, for which the *Maud* Expedition made no determinations. In the Kolyma district the mean annual change, namely, about 8′.4 west, is about the same whether the time-interval is taken from 1822 to 1909 or over the shorter more recent period of the *Maud* Expedition.

Two regions of considerable local disturbance were found in the Arctic Ocean by observations on the ice over water about 40 to 70 meters deep. The slow movement of the ship resulted in the accumulation of a large number of observations, sufficient to determine without question the existence of such disturbances. One of these regions is in north latitude 76° and between 163° and 168° east longitude, and the other in about the same latitude in east longitude 155°.

During the second part of the Expedition (1922 to 1925) systematic observations of the atmospheric-electric potential-gradient were made. Eye-readings were arranged during the first winter as no registering apparatus had been provided. Aside from the physical hardship imposed by the necessity to observe throughout the 24 hours of the day at the desired intervals, meteorological conditions interfered seriously with this work. A number of successful runs were made, however which agreed well with results obtained by the *Carnegie* over all oceans, and confirmed the conclusion that the chief wave of the diurnal variation for the atmospheric potential-gradient follows universal time. To secure the large number of runs essential for establishing this result, a recording instrument was needed, and this was produced by the ingenuity and mechanical skill of O. Dahl, the aviator. This extemporized but efficient instrument, gave good results during the two succeed-

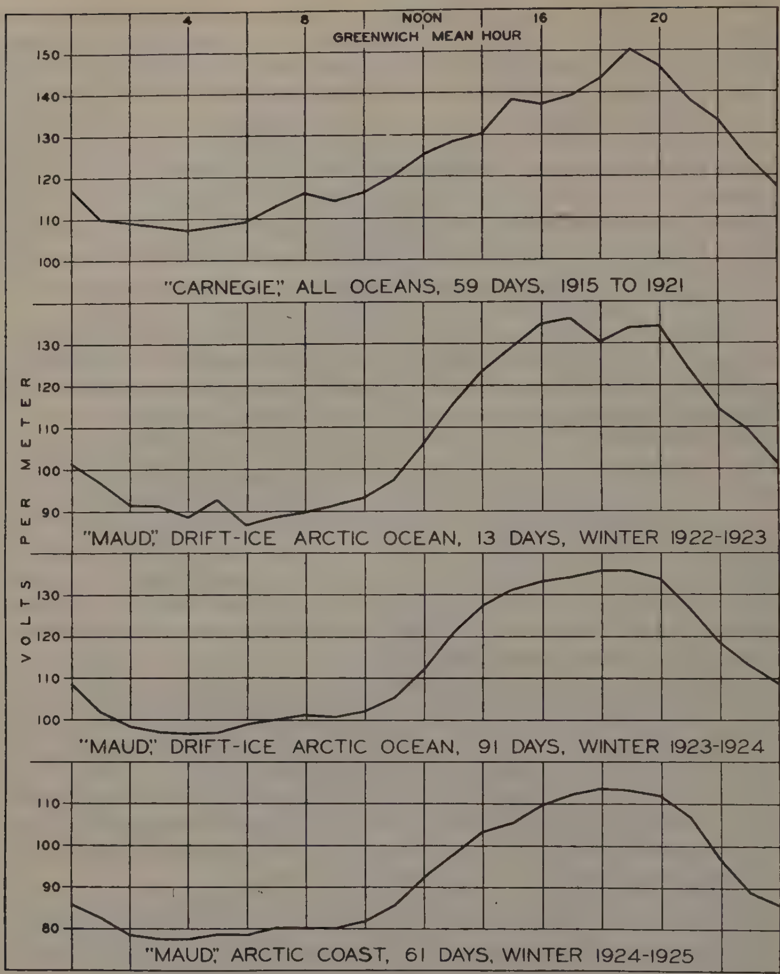

FIG. 2—Daily variation of atmospheric potential-gradient, showing simultaneous predominant 24-hour wave for the *Carnegie* results, all oceans, 1915-21, and for the *Maud* drift-ice and Arctic-Coast observations, three winters 1922-25

ing winters. No records could be made during the summer months as it was difficult to maintain proper insulation on account of high humidity and fog then. Fig. 2 shows graphs of the results and of those obtained by the *Carnegie* party during 1915 to 1921.

From a discussion of the influence of meterological conditions on the atmospheric-electric results, particularly wind-velocities, snow-drift, fog, cloudiness, and relative humidity, the conclusion

is drawn that a definite connection between potential-gradient variations and meteorological conditions is established only for snow-drift and occasionally for fog or haze. With respect to an annual variation no evidence was found of a maximum potential-gradient around December and January, such as has been found at other stations. The results, after elimination of those days which might have been affected by snow-drift, fog, and haze, point to a maximum in April and a minimum in November. The general conclusions reached from considerations given the eye-readings of the first winter were beautifully confirmed by the photographic records.

Observing and photographing the aurora took an important place in the scientific program of the Expedition. During the first three winters, 1918 to 1921, but little was accomplished, on account of a number of circumstances which hampered the work, but during 1922 to 1925 more systematic observations were possible and some unusually fine photographs were secured. The types of the auroral appearances were recorded under five broad classes, namely, glow, arch, curtain, streamer, and corona, and observations made showing date, local mean time, form, intensity on a scale of 1 to 4, azimuth, and altitude. This extensive collection has been ably discussed with some interesting deductions. The zone of maximum auroral frequency for longitude 160° east was between latitude 77° and 78° north; near this zone the moving forms predominated but farther south the quiet forms became predominant. The average direction of arches was nearly in the magnetic prime-vertical; the average altitude of the summit rapidly decreased with decreasing latitude. The radiation-points of the coronas were somewhat under and to the west of the magnetic zenith. The auroral frequency varied during the night, having a maximum between 22^h and 2^h (L. M. T.) which was best shown in the curtains, while the frequency of the glows was greatest in the latest hours of the night. Near the maximum zone the aurora moved southward and the summit of the arches increased during the night; farther south there was no such southerly movement while there was a tendency for the summits of the arches to become lower. There was a counter-clockwise turning of the direction of the arches of about one degree an hour observed at all latitudes. The relation of auroral character-number to magnetic character-number and of auroral recurrence in relation to the Sun's rotation were confirmed. The Expedition was not equipped to study auroral spectra or the relation between auroral intensity and the intensity of radio signals. Because of the constant drift it was not possible to make paralactic photographs at two stations for determinations of auroral height.

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EIN VORSCHLAG VON LEIBNIZ ZU AUSGEDEHNTEN ERDMAGNETISCHEN BEOBACHTUNGEN

Von C. Kassner

Als im Jahre 1700 in Berlin die "Königliche Societät der Wissenschaften," später Akademie genannt, gegründet worden war, suchte Leibniz auf alle möglichen Weisen dem preussischen König Friedrich I die Förderung der Wissenschaften nahe zu legen, und so entstand im November 1701 eine Denkschrift, worin Leibniz dem König empfahl, Missionäre in besonderen Anstalten wissenschaftlich ausbilden zu lassen und sie dann nach Russland, Türkei, Persien, Indien, und China zu senden. Dort sollten sie neben ihrer Prediger-tätigkeit teils als Lehrer der Wissenschaften auftreten, teils wissenschaftliche Studien machen und so die Beziehungen dieser Länder zu Preussen fördern, was sich dann auch in Handelsgeschäften auswirken werde.

In dieser Denkschrift rät Leibniz, man solle dem jetzt nach Moskau gehenden Residenten (Gesandten) einen so vorgebildeten jungen Mann beigeben, der dann vielleicht von dem Zaren (Peter dem Grossen)[1] "in die Provinzen zu observieren geschickt würde. Es ist nämlich bekannt, dass der Zar die Schiffahrtssachen liebt, und der Kompass gleichsam als die Sache der Seefahrt zu achten ist, er aber von Norden etwas abweicht und zwar an unterschiedenen Orten unterschiedlich. Hierin steckt ein noch nicht gelöstes Rätsel der Natur, das aber, wenn es vollends entdeckt würde, ein Hilfsmittel zur Längenbestimmung und eine überaus grosse Hilfe für die Schiffsführer darbieten würde. Zu solchem Zwecke habe man schon seit langem gewünscht, dass magnetische Linien auf einer Karte oder auf einem Erdglobus gezogen werden möchten, wobei die Linien immer durch Örter mit gleicher Deklination gehen sollen. Diese Karte hat nun ein Engländer aus eignen und andern Schiffstagebüchern ganz kürzlich entworfen (Halley 1701). Weil aber die Linien darin nur auf der See gezogen sind und aufhören, wo das Land anfängt, so wäre es höchst nützlich und, um dieses Geheimnis vollends zu entdecken, dienlich, dass in Königlicher Majestät Ländern vom Rhein bis an den Pregel und dann weiter durch das Moskauische Reich bis nach Persien, Indien, und China die magnetischen Beobachtungen fortgesetzt und damit die Linien durch den nördlichen Orient, allwo man am wenigsten solche Beobachtungen hat, fortgezogen würden. Hierzu wäre jemand besonders zu instruieren, und ohne Zweifel würde der Zar auf Eurer Königlichen Majestät Empfehlung und auch aus eigener Neigung zu allem, was die Schiffahrt angeht, sich dieser Sache wie eines eignen Werkes annehmen und den Beobachter überall mit Fuhrwerk,

[1] Von hier wörtlich, aber in Hochdeutsche von mir übertragen, da es sonst nicht mehr allgemein verständlich wäre.

Unterkunft und Verpflegung versehen lassen. Solches Unternehmen würde nicht weniger für Königliche Majestät ruhmvoll und für das Publikum nützlich, als auch für das christliche Werk der Missionen erspriesslich sein."

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Charlottenburg, Germany.

PROVISIONAL SUNSPOT-NUMBERS FOR JANUARY TO MARCH, 1928

BY A. WOLFER

Day	Jan.	Feb.	Mar.	Day	Jan.	Feb.	Mar.
1	58	..	79	16	..	70	109
2	..	49	70	17	75	77	103
3	..	66	55	18	62	70	116
4	80	31	52	19	..	109	139
5	..	48	70	20	55	120	105
6	..	..	76	21	70	109	81
7	83	35	91	22	52	130	99
8	93	30	..	23	61	140	60
9	..	23	..	24	94	89	..
10	80	32	..	25	116	109	71
11	79	28	..	26	113	99	50
12	78	38	108	27	143	129	..
13	54	..	..	28	94	110	50
14	61	28	..	29	89	96	72
15	62	..	..	30	69	..	62
				31	..	..	53
				Mean.	79.2	74.6	80.5
				Days..	23	25	22

Mean provisional number for first quarter 1928: 78.1

It is to be noted that these provisional sunspot-numbers are dependent alone on observations at the Zürich Observatory. The mean provisional number for the first quarter of the year 1927 was 80.2.

Zürich Observatory.

TENTATIVE MAGNETIC VALUES AS RECORDED AT THE APIA OBSERVATORY FOR THE YEAR 1927

Continuous records of the declination and of the horizontal component of the Earth's magnetic field were obtained during 1927 at Apia Observatory, latitude 13°48′ south, longitude 171°48′ west. Owing to the length of time which must necessarily elapse before publication of the hourly values of these elements, it is considered desirable to announce tentative values which, although subject to revision, will probably remain unchanged. These data, as given in the following table, are based on the means of all the hourly values during the month giving the so-called "all-days value" for the magnetic element concerned:

Month	Hor. int.	East decl'n	
	γ	°	′
January	35223	10	27.8
February	35236	10	28.5
March	35226	10	28.7
April	35229	10	28.4
May	35225	10	29.4
June	35230	10	29.3
July	35216	10	29.5
August	35207	10	30.1
September	35216	10	30.6
October	35206	10	30.5
November	35228	10	30.2
December	35230	10	30.6

The annual values since 1921 are:

Year	Hor. int.	East decl'n	
	γ	°	′
1921	35257	10	10.7
1922	35241	10	13.6
1923	35248	10	16.3
1924	35249	10	19.2
1925	35239	10	22.8
1926	35216	10	26.1
1927	35223	10	29.4

ANDREW THOMSON, *Director;* C. J. WESTLAND, *Observer.*
Apia Observatory, Western Samoa.

EARTHQUAKE RECORDS ON MAGNETOGRAPHS AT LUKIAPANG, CHINA, 1927

Date	G.M.T.[a]	Type[b]	Variometer
1927	*h m*		
Feb. 3	3 52	..	H, D, Z
Feb. 3	4 51	..	H, D
Feb. 19	6 53	a	H, D
Feb. 22	20 06	c	H
Mar. 7	17 35	c	H, D, Z
May 22	22 39	a	H, D, Z
Aug. 5	21 28	c	H
Aug. 24	18 15	b	H, D
Nov. 5	14 42	c	H

[a]Time of first indication on the bifilar instrument.
[b]*Cf. Etude*, XXIV, IV, p. 11.

J. DE MOIDREY, S. J.

Lukiapang, China,
March 12, 1928.

PRINCIPAL MAGNETIC STORMS RECORDED AT THE SITKA MAGNETIC OBSERVATORY, OCTOBER TO DECEMBER, 1927[1]

(*Lat. 57° 03′.0 N.; long. 135° 20′.1 or 9^h 01^m.3 W. of Gr.*)

Greenwich Mean Time				Range		
Beginning		Ending		Decl'n	Hor. int.	Vert. int.
1927	*h m*	*d h*	*m*	′	γ	γ
Oct. 7	9 06	8 15	..	61.9	673	602*
Oct. 9	20 34	11 3	..	51.4	920*	390*
Oct. 12	10 27	13 21	..	225.2	921*	784*
Oct. 22	6 39	24 6	..	227.9	1335**	482*
Dec. 13	9 52	14 12	..	116.2	958	549

*Curve went off the paper in one direction.
**Curve went off the paper in both directions.

October 9–11, 1927.—This storm is peculiar because of the short rapid oscillations of the elements on October 10 at 13^h to 23^h. After 15^h the mean values of the oscillations are about the mean values of the normal curves. The oscillations are so rapid that the curves are mostly spots up to 21^h, but, each curve being separated, the path can be accurately determined.

October 12, 1927—The motion of the curves is so rapid that in places the curves consist of spots only from 11^h to 17^h. At that time the trace was changed and the light increased. From 17^h to 22^h the curves consist of fairly large rapid oscillations.

October 22, 1927.—This storm is characterized by a very sudden beginning. From normal regular curves, all elements suddenly

[1]Communicated by E. LESTER JONES, Director, United States Coast and Geodetic Survey.

decrease and then almost immediately increase a larger amount. At 17^h the storm is almost gone, but small slow oscillations continue until 23^d1^h, when the storm becomes more active, and at 23^d4^h a great magnetic storm is in progress. Large rapid oscillations, almost the width of the magnetogram, occur to 12^h, when the storm begins to decrease in intensity. The ranges in declination and horizontal intensity were very large, the horizontal-intensity range being the maximum that could be recorded.

F. P. Ulrich, *Observer-in-Charge.*

PRINCIPAL MAGNETIC STORMS RECORDED AT THE HUANCAYO MAGNETIC OBSERVATORY, AUGUST TO DECEMBER, 1927

(*Lat.* 12° 02′.7 *S.*; *long.* 75° 20′.4 *or* 5^h 01^m *W. of Gr.*)

Greenwich Mean Time							Range		
Beginning			Ending						
							Decl'n	Hor. int.	Vert. int.
1927	*h*	*m*	*d*	*h*	*m*			γ	γ
Aug. 19	11	55	21	19	..		9.4	350	45
Sep. 10	13	31	10	22	16		5.2	247	17
Oct. 10	8	23	10	22	20		9.3	289	19
Oct. 12	10	25	13	18	..		13.5	763	37
Oct. 22	6	38	24	05	..		11.5	388	28
Nov. 18	4	33	18	17	..		7.4	303	20
Dec. 12	19	43	14	15	..		12.5	*	30
Dec. 17	5	13	17	20	..		7.3	181	25

*Greater than 350 gammas.

August 19-21, 1927.—A mild magnetic storm began at 11^h55^m on August 19, with a small but abrupt change in the horizontal intensity and the declination but with hardly noticeable change in the vertical intensity. The storm is prominent for duration rather than for large or severe perturbations. From the commencement until 20^h on the 20th the usual diurnal variation is followed but with occasional small peaks and bays breaking up the uniform trend. After 20^h on the 20th, a large decrease in horizontal intensity occurs, with a sharp drop between 22^h13^m and 22^h40^m of about 130 gammas. Thereafter the perturbations are more severe, with very low intensity continuing until 5^h on the 21st. A peak occurs at 8^h, resulting from a sharp increase of about 220 gammas within 15 minutes. Thereafter the intensity rises from a minimum at $12^h.5$ to the usual diurnal maximum between 15^h and 19^h, with the latter period exhibiting an abnormal saw-toothed formation. After 19^h on the 21st the storm ceases, although the recovery to normal intensity is not complete until approximately 12^h on the 23d. The disturbances of declination and vertical intensity are small, with the greatest perturbations occurring between 20^h on the 20th and 3^h on the 21st, between 8^h and 10^h on the 21st, and, to a lesser degree, between 15^h and 19^h on the 21st. A pro-

nounced minimum in the vertical intensity occurs at 18^h on the 20th.

August 29-30, 1927.—A very mild but prolonged disturbance, hardly to be classed as a storm, began abruptly in the horizontal intensity at 0^h00^m on August 29, with an increase of 67 gammas within 5 minutes. The disturbance began in declination and vertical intensity at 0^h02^m with small but abrupt changes. After the sudden commencement the usual diurnal variation is followed but with minor perturbations which, over occasional periods, give the horizontal intensity trace a saw-toothed appearance. The general diurnal trend is interrupted for the period 10^h to 19^h on the 30th, a minimum being reached at 12^h51^m, the intensity then rising through minor perturbations to a sub-normal maximum. After 19^h on the 30th there is a return to more quiet conditions although for several days afterward the intensity is subject to continuous minor disturbances.

September 10, 1927.—A magnetic storm of very moderate severity and short duration began at 13^h31^m on September 10, with a decrease in the horizontal intensity but with no prominent change in declination or vertical intensity, and continued until 22^h16^m on the same day. During the period of the storm there are two peaks on the horizontal intensity (at approximately 18^h and 20^h) and one bay beginning at 21^h18^m, the intensity decreasing 81 gammas in nine minutes. The horizontal-intensity record, throughout the storm interval, has a small saw-toothed formation. The storm occupies the period of the diurnal maximum. The declination and vertical-intensity records exhibit only minor perturbations.

Notes, September, 1927.—At the periods of diurnal maximum (between 11^h and 21^h) on September 1, 4, 7, 8, 9, 11, 20, 25, 26, and 29, there were marked disturbances, with peaks and bays, but the generally disturbed character of the magnetic elements during the month made these of minor importance and not to be classed as storms.

October 10, 1927.—A magnetic storm of moderate severity began at 8^h23^m on October 10 with marked perturbations in all three elements, the horizontal and vertical intensities both increasing by small amounts, the declination decreasing slightly. The storm ended at 22^h20^m on the same day. The declination and vertical-intensity records have a saw-toothed formation throughout the storm, otherwise following the usual diurnal trend. The horizontal-intensity records likewise essentially follow the usual diurnal trend but the saw-toothed formation is more pronounced and the fluctuations so rapid as to, at times, prevent recording.

October 12, 1927.—A magnetic storm of great severity began abruptly at 10^h25^m on October 12 in all three elements, the intensity-changes being small but prominent. The storm ended at approximately 18^h on October 13. From the commencement until 21^h on the 12th, the horizontal-intensity record is characterized by extremely large and rapid saw-toothed perturbations and the

declination and vertical intensity by less rapid and smaller, but for those elements at this station, unusually large perturbations. The peaks and bays in the horizontal intensity during this storm follow each other at very short intervals. After 21^h on the 12th and until after 13^h on the 13th, the horizontal-intensity record shows very minor peaks and bays with the intensity below normal, while the declination and horizontal intensity show occasional small disturbances. Between 13^h and 18^h on the 13th the horizontal intensity is disturbed by three peaks and two bays of moderate severity, while the declination and vertical intensity show unusual but minor perturbations. The effect of this storm continued for the succeeding two days, the periods of diurnal minimum in horizontal intensity being low.

October 22, 1927.—A magnetic storm of moderate severity began abruptly at 6^h38^m on October 22, with an increase of 102 gammas in horizontal intensity within two minutes and small but prominent increases in declination and vertical intensity. Within an hour after the commencement the horizontal intensity reached a maximum, thereafter decreasing gradually and continuously until 10^h23^m, the decrease being 326 gammas. Declination and vertical intensity show small but prominent changes during this interval. From 12^h to 16^h on the 22d the perturbations in horizontal intensity are so rapid as to, at times, prevent recording, while declination and vertical intensity show small saw-toothed perturbations. After 16^h on the 22d and until the end of the storm at 5^h on the 24th, the horizontal intensity is characterized by moderately large peaks and bays but no rapid changes, while declination and vertical intensity show minor disturbances. The effect of this storm continues to show by low intensity during the diurnal minimum on the succeeding three days.

Notes, October, 1927.—From 13^h on October 7 until 8^h on the 8th, a moderate disturbance affected all three elements, causing very minor perturbations in declination and vertical intensity and moderately large peaks and bays in horizontal intensity between 13^h and 18^h on the 7th and a sub-normal intensity from 19^h on the 7th to 8^h on the 8th.

Again on the 9th, between 15^h and 22^h, the horizontal intensity shows moderate peaks and bays with a sudden decrease of 83 gammas within a period of fifteen minutes after 17^h33^m.

November 18, 1927.—A storm of moderate intensity, marked by large bays and peaks without rapid fluctuations, began abruptly in all three elements at 4^h33^m on November 18, with small increases in horizontal intensity and vertical intensity and a small decrease in declination. For seven hours after the commencement the intensities were little disturbed. After 11^h a sudden increase in horizontal intensity occurred, followed at rapid intervals, until 17^h, by other large peaks and bays. Thereafter, until 19^h on the 19th, the horizontal intensity was disturbed only by minor peaks and bays in the usual diurnal trend, though the intensity was some-

what below normal, with the exception of a sudden change beginning at 16^h10^m on the 19th, causing a decrease of 92γ in twenty-one minutes.

Notes, November, 1927.—At the periods of diurnal maximum (between 11^h and 21^h) on November 4, 5, 9, 21, 24, 27, 29, 30, there are marked disturbances in the horizontal intensity, but the generally disturbed character of the magnetic elements during the month made these of minor importance and not to be classed as storms.

December 12, 1927.—A storm of moderate severity began abruptly December 12, at 19^h43^m, with an increase in horizontal intensity of 56 gammas within four minutes, and much smaller but prominent increases in declination and vertical intensity. Thereafter, until 9^h on the 13th, the elements were disturbed very little. At 12^h39^m on the 13th, all elements again suddenly became disturbed, the horizontal intensity being characterized by very large and moderately rapid fluctuations and the declination and vertical intensity by smaller but very abnormal changes. This phase continued until 6^h14^m on the 14th. Thereafter, until 10^h, the elements were comparatively undisturbed. At 10^h all elements became moderately disturbed, the horizontal intensity showing small but rapid peak and bay formations until 15^h, when the fluctuations became less rapid. The declination and vertical intensity were only slightly disturbed during this interval. After 15^h on the 14th and until 23^h on the 15th, all elements show minor disturbances characteristic of the disturbed conditions prevailing through the first half of the month.

December 17, 1927.—A mild magnetic storm of very brief duration but of prolonged effect, began abruptly at 5^h13^m on December 17 with small but prominent changes in all three elements. Thereafter, until 13^h, the elements were only slightly disturbed. After 13^h and until 20^h, the declination and vertical intensity showed very minor perturbations and the horizontal intensity was disturbed by two moderate peaks and one bay. After 20^h on the 17th the larger disturbance ceased but the effect of this storm is continued until 23^h on the 19th, as indicated by very low intensity-values in horizontal intensity. At 14^h on the 18th there was a sudden decrease of 112 gammas in horizontal intensity with corresponding abrupt but minor changes in declination and vertical intensity. After this decrease the usual diurnal maximum did not occur but was almost entirely absent.

Notes, December, 1927.—At the periods of diurnal maximum (between 10^h and 22^h) on December 1, 2, 5, 6, 9, 10, 28, there were marked disturbances in the horizontal intensity, but the generally disturbed character of the magnetic elements during the month made these of minor importance and not to be classed as storms.

All times given are Greenwich civil mean time.

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REVIEWS AND ABSTRACTS

(See also page 14)

D. W. Dye: *A magnetometer for the measurement of the Earth's vertical magnetic intensity in C. G. S. measure.* (London, Proc. R. Soc., A, vol. 117, pp. 434-459.).

A pair of Helmholtz coils was set up with axis vertical and a current was passed through them so as to compensate the vertical component of the Earth's field. The dimensions of the coils and the current through them give directly the vertical component.

In order to find when the vertical component inside the Helmholtz coils was zero, a small coil was suspended on a stretched phosphor-bronze suspension inside of them. An alternating current was sent through the coil, the plane of the coil being vertical. Under these conditions the vertical component of the steady field inside the Helmholtz coils produced a periodic force on the suspended search-coil, the vibration of which was observed by means of mirror and scale. The current through the compensating coils was adjusted until the vibration disappeared. Under these conditions, if proper precautions are taken, the vertical component of the field inside the Helmholtz coils is zero.

The search-coil had 100 turns of wire 0.05 mm in diameter and its length was about 2 cm and its width about 1 cm. Its mass, including the mirror, was about 150 gm. The current through it was in the neighborhood of 70 milliamperes and the frequency of the current about 15 cycles per second. The tension on the phosphor-bronze suspension was adjusted so as to make the period of free vibration of the coil about one-fifteenth second and thus to magnify the sensitivity by resonance. It is stated that a vibration of 0.1 mm with a 2-meter scale distance could be detected corresponding to a sensitivity of 0.16γ (25 mm = $40\,\gamma$). The imperfection of alignment and a wave-form may make the inaccuracy greater than that. It is of interest, however, to note that the intrinsic sensitivity has the above favorable value.

The imperfection of alignment has been treated and practically eliminated by adjustment until turning about a vertical axis made no difference in the reading. When this is the case, the plane of the coil must be vertical and its axis of vibration horizontal. Besides it may be shown that the mean of two observations in which the coil has been turned through 180° about a vertical axis, should give the correct value. Using this method of means and considering the possible uncertainty of knowing when the coil has been turned through 180° to be 1/1000 radian (0.05°) it is estimated that the vertical intensity can be measured with an uncertainty of less than one part in 100,000 unless the horizontal intensity is more than ten times the vertical intensity. It may be noted, however, that if the horizontal intensity should be high, the accuracy of adjusting the axis and plane of the coil will be also increased so that even close to the magnetic equator accurate settings may be possible. Practically the same order of magnitude of uncertainty arises from the imperfection of adjusting the axis of orientation of the coil to the vertical. This is due to the fact that the angle between the axis of orientation (the axis of the turntable on which the coil is mounted) and the vertical cannot in the instrument in question be adjusted better than to 1/50,000 radian (0.001°) and that this angle enters into the measurement to the

first order, viz, as H ψ. This error can hardly be considered as reflecting on the possibilities of the present method because it is inherent in any method, since the vertical must be defined before the vertical intensity can be measured.

The current through the Helmholtz coils was measured either by means of an independent potentiometer or else by means of a direct potentiometer-method, i. e. by balancing the potential-drop across a resistance against a standard cell. Two forms of connections are suggested having reference to ease of adjustment as well as to accuracy.

Some difficulty has been experienced with sources of current other than a rotary converter. This was due to the presence of harmonics and consequent heating effects. Particularly the second and other even harmonics are troublesome because their presence produces a vibratory force with the fundamental frequency which is in tune with the coil mechanically.

Readings were taken by means of the magnetometer with the simultaneous observations on a recording magnetograph. The comparison was not made in absolute values but only in the "γ-differences." Assuming the recording magnetograph to be correct after a temperature correction has been applied the author concludes that the mean variation from the mean in "γ-differences" was about 0.8γ and the maximum variation from the mean was 1.2γ. With steady magnetic conditions the mean base line given by 30 observations within an hour, can be determined with a certainty of 0.3γ.

The practical advantage of the present method consists in avoiding rotating parts which are usually subject to wear. The rotation is transferred to the rotary converter used as a source of alternating current where it causes no trouble. The search-coil is very small in comparison with the Helmholtz coils so that exact compensation may be obtained.

The instrument is perhaps not readily adaptable to continuous recording in its present form. A combination of two instruments, one with high and the other with low sensitivity, may prove satisfactory if a method is devised for damping excessive amplitudes on oscillations in the high sensitivity instrument.

G. Breit.

A. Nippoldt: *Karten der Verteilung des Erdmagnetismus und seiner örtlichen Störungen in Europa.* Archiv des Erdmagnetismus Heft 6 (Berlin, Veröff. Met. Inst., Nr. 354, Bd. 7, Nr. 11, 1927, 42 pp. 4 Karten. 33 cm.)

The comparatively dense though by no means uniform distribution of magnetic stations over Europe, and the large number of observatories which furnish means of reducing field observations to a common epoch, make possible a more thorough and satisfactory discussion of magnetic distribution over that continent than can be made for any other area of similar extent. Notwithstanding these favorable conditions there has never been made until now an attempt to combine all the available material in a single discussion, and from it to present a comprehensive picture of the magnetic field as a whole with its irregularities and their relation to other geophysical facts. Many investigators have worked on this material but too often have confined their studies within their own national boundaries, contributing in this way to the building of a magnetic chart of the whole Earth. This limitation has resulted in a weakness of determination especially with reference to anomalies along the boundaries, which often fall along the mountain ranges where the most interesting conditions are likely to prevail.

Observations at approximately 7000 field stations were available for this

general consideration of the entire area of Europe including the British Isles, a part of Asia Minor, and north Africa. More or less complete data from more than 20 observatories contributed to the reduction to the chosen epoch, 1921.0. The coordination of the several observatories was made by reduction to the provisional International Magnetic Standards (*I.M.S.*) by means of intercomparisons obtained largely by the work of the Carnegie Institution of Washington. Following the reduction of this mass of material to a common basis, the results were set down on outline maps of large scale, and the true isomagnetic lines in declination, D, horizontal intensity, H, and vertical intensity, Z, were drawn without smoothing out the irregularities. These three maps have been reproduced on a scale of about 1:6,500,000, and accompany the paper as an appendix.

In the discussion of magnetic disturbances, it was the author's purpose to separate from the total field that part which is permanently associated with the European portion of the Earth's crust, and that necessitated the elimination of the uniform field and the regional portion of the residual field. By the uniform field is here meant that portion represented by the first term in the spherical harmonic analysis usually described as the homogeneous field.

Using the latest analysis, that of L. A. Bauer for the year 1922, and confining the discussion to the disturbances in the vertical component, he finds values for each of the European observatories from the formula

$$Z_h = 0.620 \sin\phi + 0.0426 \cos\phi \cos\lambda - 0.1178 \cos\phi \sin\lambda$$

When this "quasi-homogeneous" field is subtracted from the observed values at each observatory station, there remain residuals of negative sign in all but two cases, those at Ekaterinburg (Sverdlovsk) and Tiflis-Karsani at the extreme eastern edge of the region considered. The negative values become progressively greater towards the west being -8460γ and -8750γ respectively at Valencia and Eskdalemuir. With these observatory values as a basis, lines of equal magnetic disturbance are graphically drawn which show this "European-regional disturbance". The value of δZ, the true local disturbance is then given by the expression

$$\delta Z = Z_b - (Z_h + Z_r)$$

in which Z_b is the observed value and Z_r is the regional disturbance as determined by the graphical process. In this way values of Z_r are found for the intersections of each half-degree of latitude and each degree of longitude. After plotting these disturbance-residuals and drawing the lines of equal disturbance, it is possible to make comparisons between their distribution and the underlying geographical structure. It is assumed that this chart is a permanent one, not referred to an epoch, inasmuch as it represents conditions inherent in the physical conditions of the rocks themselves, and not subject to secular changes; the only modifications which may in the future be necessary being those arising from the accumulation of more data and further refinements of reduction.

Such knowledge as we have of the magnetic properties of various kinds of rock and mineral occurring in the Earth's crust may not be conclusive when applied to the conditions existing in nature where the magnetizing forces are much weaker than those employed in the laboratory. It is certain however that some rock-masses possess a permanent magnetism not derived from induction. This is shown by the occurrence of the disturbances with a sign opposite to that which an induced magnetism would produce. A correlation of the principal features of

this disturbance-chart with the known geological structure of Europe makes it possible to group the disturbances under three heads: Those arising from crystalline rocks, as in Finland and southern Sweden; the effects of volcanic material, both the older and the more recent as in Hebrides and Auvergne; and those of greater extent connected with tertiary mountain formations. The effects of the volcanic rocks are likely to be so local in character that they do not appear on a map of the scale of the one used; they are also often found in close relation to the crystalline rocks so that the effects from the two sources are difficult to separate; the signs of the disturbances of this group are quite arbitrary, occurring both as positive and as negative.

The relations of magnetic anomalies with those of gravity are more difficult to establish, partly because of the lack of detailed gravity observations in some regions and partly because of the difference in the methods used in reducing the two kinds of observations. In general, it is shown that the principal gravity anomaly along the region of the Alps, coincides with the magnetic disturbance-system. Nevertheless, many localities of strong magnetic disturbance are unaccompanied by corresponding irregularities in the gravity chart as drawn up by Kossmat and Lisner with which comparison is made. The heaviest rocks are by no means the most strongly magnetized and strongly magnetized rocks may be so scattered that they produce no gravity effect. Each method, therefore, may be made to supplement the other in geophysical investigations.

H. W. FISK.

K. KÄHLER: *Über die elektrischen Vorgänge im Gewitter.* (Met. Zs., Braunschweig, Bd. 44, Heft 12, 1927, pp. 441-453.)

The modern developments have largely followed experimental work by C. T. R. Wilson (England), whose papers had not been available to Kähler until after Kähler's own book was written (1924), and H. Norinder (Sweden), both of whom proceeded with the fundamental idea of basing their conclusions concerning the nature of lightning discharges on observed changes in the electrical field at the Earth's surface during thunderstorms. As the method employed in the usual potential-gradient observations is too slow for measuring the rapid changes in the Earth's field during lightning discharges, the making of satisfactory observations required the introduction of more accurate and more rapid registration.

Dr. Kähler gives the fundamental equations of Wilson together with certain theoretical developments by others, especially by Appleton, Watt, and Herd. The breaking-drop theory of G. C. Simpson is also briefly given, and the essential differences between the Wilson and Simpson assumptions are discussed in the light of recent observational results. The methods first used by Wilson for measuring and recording electrical discharges in thunderstorms were described by him in 1916 and again used by him in improved form in his subsequent work. Appleton, Watt, and Herd, as also Schonland and Craib, used the Wilson methods, but the former used a string electrometer for some of their observations instead of Wilson's capillary electrometer. However, even the Wilson methods are too sluggish for recording the short, rapid fluctuations of the Earth's field due to lightning, especially the electromagnetic atmospheric disturbances which are often caused by distant thunderstorms. The efforts to measure these rapid disturbances have led to apparatus involving the use of the Braun tube. This method was developed especially by Watson Watt in England and H. Norinder

in Sweden. Since 1923 Norinder has used, instead of an elevated metal sphere, a long horizontal conducting antenna in which currents are induced by the rapid time-variations of the Earth's field and are registered by the oscillograph. This arrangement has been adopted by the Studien Gesellschaft für Höchstspannungsanlagen, Berlin, which maintains an experimental station at Wünsdorf for the study of lightning under the leadership of A. Matthias. Dr. Kähler states that the measurements made by Matthias constitute a great advance over all earlier ones because here all the effects of lightning are simultaneously recorded so that unequivocal conclusions may be drawn from the field changes regarding the direction of the current of lightning. While Appleton, Watt, and Herd at first used a spherical metal conductor, they later employed an L-shaped aerial conductor 500 meters long and 15 meters high. With this and a cathode-ray oscillograph they were able to determine field changes to 0.01 volt per meter.

The author makes many comparisons and summaries of the results obtained by different investigators. Space will here allow mention of only a few of these to indicate some of the main results and outstanding problems.

For example, Wilson in England found from 16 summer storms, distant from 3 to 30 kilometers, comprising about 1,000 field changes, the relation of positive to negative values of about 1.5:1. Appleton, Watt, and Herd at Helwan and Khartoum, working with relatively much more distant storms, found negative field changes very greatly in excess. The measurements by Schonland and Craib in South Africa gave for the near storms an excess of positive and for the distant storms predominantly negative field changes. Measurements have been made on a sufficient number of storms (approaching or receding) to show that the same storm which gives excess of positive field changes when only several kilometers from the observing station will give an excess of negative at distances beyond 8 or 10 kilometers. Most of the lightning discharges could be identified as cloud lightning, and the infrequent earth lightning nearly always brought positive field changes. These measurements confirm Wilson's view that cloud lightning discharges may, on approaching, undergo a reversal of sign of the field changes produced without change in the arrangement of its charge.

Similar comparison summaries are made regarding the average and maximum field intensities measured by different observers and in different regions, the average electric moments of the discharges, the average and maximum current of lightning discharges, and various other interesting features.

Wilson's idea of the distribution of electricity in charged clouds is rather thoroughly discussed both with respect to ordinary rain clouds and thunderstorm clouds. Criticisms of Simpson and of Appleton are also introduced. While Wilson holds that the observed facts of the thundercloud are best explained by assuming a positive bipolar cloud, *i.e.*, that the cloud consists of two charges of opposite sign one above the other, and that most frequently the upper one is positive, Kähler believes that a very important contribution by Wilson is his suggestion regarding the processes above the thundercloud in the upper atmosphere.

Although Simpson rejects Wilson's explanation of the maintenance of the Earth's negative charge by the apparent preponderance of negative lightning to Earth, Appleton, Watt, and Herd believe the results of their measurements are confirmatory of Wilson's point of view. Schonland and Craib, too, as well as Appleton, Watt, and Herd, believe that their results can be explained by a charge distribution in which the positive cloud charge is above the negative.

A theory of cloud electrification recently put forth by Töpler is discussed.

As does Simpson, Töpler assumes a negative bipolar cloud. While the theory would explain certain phenomena, the author states that it does not fit the observed facts.

Simpson's modified theory (1927) is examined point by point and compared with those of others. As already noted, he alone of the English investigators assumes a negatively bipolar thundercloud. It is also shown that the ratio 4:1 for positive to negative lightning as determined by Simpson from his laboratory experiments and study of lightning photographs is decidedly in disagreement with results of Mathias, who found a ratio of 6:1 negative to positive at the Wünsdorf station. The discussion of Simpson's use of the Lenard effect is also of interest. It is pointed out that Simpson's classification of lightning discharges differs from Wilson's and that when the data of Appleton, Watt, and Herd and those of Schonland and Craib are reclassified and examined by Simpson he finds them "in good accord with the breaking-drop theory."

Summarizing, the author says "that even the Simpson theory of thunderstorm mechanism, however stimulating it is and however cleverly it seeks to explain all data, still does not hold for all the observed facts. It is on the whole doubtful if it may be accomplished with so simple a scheme as is the bipolar cloud."

A bibliography of the recent papers on the subject accompanies the paper.

S. J. MAUCHLY.

F. BĚHOUNEK: *Recherche sur l' électricité et la radioactivité de l' atmosphère au Spitzberg.* J. Physique et Le Radium, Paris, Série VI, T. 8, No. 4, 1927 (161-181).

During the Amundsen-Ellsworth-Nobile Polar Expedition, continuous observations of the ionization and radioactivity of the atmosphere were carried out at Kings Bay, Spitzbergen. There were found for the number of light ions and the atmospheric conductivity, values which, on the average, do not differ from those found on the continents, however, the mobility of the ions showed rather variable values and generally of the order of 1 cm/sec/1 v/cm. A series of observations of the space-charge of the atmosphere was also made, using Obolensky's method. The results showed that the number of large ions (Langevin ions) is of the same order of magnitude as on the continents. High values of the potential gradient were found (on the average 191 v/m). The intensity of the vertical atmospheric-electric current while being, on the average equal to that found in temperate climates, often gave values many times greater than the mean value. The results of the investigations of the atmospheric radioactivity, showed within the limits of sensitivity of the instrument used, relatively small content thus confirming the explanation of the radio-activity of the lower layers of the atmosphere as due to the constant emanation of radon from the soil. A theoretical discussion of the method employed (active deposit method) is given as well as a discussion of the results obtained for the characteristics of atmospheric electricity in connection with the ultra-penetrating radiation of the atmosphere. A description is also given of an attempt to determine the electronic current necessary to maintain the Earth's negative charge. The negative result of this attempt and of similar experiments of Swann and Schweidler is explained on the hypothesis of Swann's high-speed electrons, the effects of which on the instruments used would be of the order of errors of observation.

H. D. HARRADON.

NOTES

(See also pages 25 and 26)

8. *International Geodetic and Geophysical Union.*—The Fourth General Assembly of the International Geodetic and Geophysical Union will be held at Stockholm, Sweden, August 18 to 25, 1930, sections having the privilege of beginning work August 13, if desired.

9. *Arktis.*—The Internationale Studiengesellschaft zur Erforschung der Arktis mit dem Luftschiff (Aeroarctic) is about to publish the first number of a new quarterly journal, *Arktis.* It is the intention of the Society to make this journal primarily the organ of polar science with particular emphasis on polar exploration by means of the airship, but it will also contain studies and investigations of more general scientific nature pertaining to the arctic and antarctic regions and even articles dealing with navigation and the exploitation of natural resources in polar regions, as, for example, seal fisheries and coal deposits will be admitted to its columns. The journal is issued from the press of Justus Perthes in Gotha and the price of the annual subscription is fixed at $4.00 or 16 marks.

10. *Magnetic Character of Days in January and February 1928.*—The report by George Hartnell of magnetic character of days for the months of January and February 1928 from the Cheltenham Magnetic Observatory of the U. S. Coast and Geodetic Survey shows the unusual circumstance of only one disturbed day, namely, January 27, and that of character 1, during the two months.

11. *Magnetic Observations at Prague and O'Gyalla.*—The first issue of the "Rocenka" (year-book) for 1927 of the Geophysical Institute of the Czecho-slovak Republic states that it was necessary in May of that year to suspend entirely the magnetic declination observations which had been made regularly at Prague since 1839. The extension of the electric railway and lighting systems had made horizontal-intensity observations impossible from 1904. Work at the O'gyalla Observatory, discontinued in 1918, was resumed in 1924. It is expected that a new observatory replacing that of Prague will soon be erected and that magnetic results there obtained, along with those at O'Gyalla, will be published regularly in a special bulletin.

12. *Personalia.*—Dr. *H. A. Lorentz,* for many years professor of theoretical physics in the University of Leiden, died on February 4, 1928, aged 74 years. He will be succeeded by Professor *Ehrenfest.* Mr. *E. W. Maunder,* who was for many years superintendent of the solar department of the Royal Observatory at Greenwich, died on March 21, aged 76 years.

Dr. *Charles K. Edmunds,* formerly president of Canton Christian College, who for several years was engaged in the magnetic survey of China for the Department of Terrestrial Magnetism, has accepted the presidency of Pomona College, Claremont, California. He will assume office about May 1, 1928.

H. E. McComb, while at San Juan, Porto Rico, inspecting the new observatory of the United States Coast and Geodetic Survey, made improvements in operating details to solve some of the instrumental problems caused by the extremely humid climate there.

The degree of Doctor of Science has been awarded by the University of Cambridge to Mr. *F. J. W. Whipple,* superintendent of the Kew Observatory and assistant director of the Meteorological Office.

LIST OF RECENT PUBLICATIONS

By H. D Harradon

A—Terrestrial and Cosmical Magnetism

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Apia Observatory. Report for 1925. Published by the direction of the Honorary Board of Advice, Wellington, N. Z. Wellington, W. A. G. Skinner, Govt. Printer, 1927 (95 with 3 pls.). 25 cm.

Bahurin, I. The magnetic field of bodies of regular shape from the viewpoint of magnetometric studies. Leningrad, Bull. Inst. Prac. Geophys., No. 2, 1926 (3-64). [Russian text with English abstract.]

The work of the Institute of Practical Geophysics on the brown iron ore deposits. Leningrad, Bull. Inst. Prac. Geophys., No. 2, 1926 (65-82). [Russian text with English abstract.]

The magnetic observatory in the coal basin of Don and magnetic survey near Makeyevka. Leningrad, Bull. Inst. Prac. Geophys., No. 2, 1926 (96-106). [Russian text with English abstract.]

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Bellocq, H., et Ch. Jacquet. Mesures magnétiques dans les Basses-Pyrénées, les Landes et la Gironde. Paris, C.-R. Acad. sci., T. 186, No. 7, 1928 (448-450).

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Note on the mean monthly values and the annual inequalities of the magnetic elements. London, Mon. Not. R. Astr. Soc., Geophys. Sup., v. 1, No. 10, 1928 (532-541).

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B—Terrestrial and Cosmical Electricity

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Terrestrial Magnetism
and
Atmospheric Electricity

VOLUME 33 JUNE, 1928 No. 2

THE SENSITIVITY OF MAGNETIC VARIOMETERS[1]

BY H. E. McCOMB

Abstract—Variation with ordinate in sensitivity of the horizontal-intensity variometer, San Juan Magnetic Observatory, Porto Rico, was determined in a short time by observing scale-values over a wide range of ordinate, the ordinate being changed by torsion or by an auxiliary deflector. In order to test the efficiency of a new type of vertical-intensity variometer pivot, scale-values were observed at Cheltenham Magnetic Observatory, Maryland, U. S. A., over the complete range of sensitivity of the recording magnet-system by method of deflections, of oscillations, and of weights. The values obtained from deflections were reconciled by the adoption of proper distribution-coefficients using the method of least-squares for their determination. The paper summarizes and discusses briefly the experimental data obtained at the two observatories.

In order to test the efficiency of the horizontal-intensity (H) variometer at the San Juan Magnetic Observatory in the very limited time available, scale-value observations were made first at a wide range in sensitivity with fairly constant ordinate and then over a wide range in ordinate with constant position of the sensitivity magnet. The magnet which controls to a large extent the sensitivity of the recording magnet is oriented with its north end east and in the magnetic prime-vertical east or west of the recording magnet and at the same elevation. The sensitivity may be adjusted to the desired value by fixing this control-magnet at some definite position on its bar.

The first series of observations began with the sensitivity magnet well removed from the H-variometer after which observations were made with the magnet at each of five different positions on the bar. The observations consisted of the usual deflections of the H and D variometers but at one deflection distance only.

[1]Published with the permission of the Director of the U. S. Coast and Geodetic Survey.

The results are given in Table 1 and shown graphically in Figure 1. The scale-values were computed from the equation[2]

$$\epsilon_h = (2u/2u')\,(H/2R)\,(f/(f-h)) \tag{1}$$

in which ϵ_h = the scale-value in gammas per millimeter, $2u$ = the double deflection of the D-curve, $2u'$ = the double deflection of the H-curve, H = the horizontal intensity in gammas, R = distance from D-lens to magnetogram, h = angle through which magnet is turned when the torsion-head is turned through an angle f.

TABLE 1—*Variation of horizontal-intensity scale-value with sensitivity-magnet for Toepfer variometer X at San Juan, Porto Rico, January 25, 1928*

Quantity	Distance of center of sensitivity-magnet to center of variometer in cm				
	Away	14.0	13.0	12.0	11.0
Undeflected ordinate, h, in mm....	30.0	33.0	19.0	26.6	28.0
Double deflection, $2u'$, in mm....	62.2	85.4	96.7	112.0	147.0
Scale-value ϵ'_h in gammas........	5.59	4.07	3.60	3.11	2.37
Scale-value ϵ_h in gammas at zero-ordinate	5.49	3.96	3.53	3.02	2.27

As these preliminary results seemed to be consistent it was decided that a scale-value of about 2.6 gammas for zero-ordinate would be a satisfactory working value and the sensitivity magnet was adjusted to this position by use of the graph in Figure 1.

[2]D. L. HAZARD, Directions for magnetic measurements, p. 103, second edition (1921).

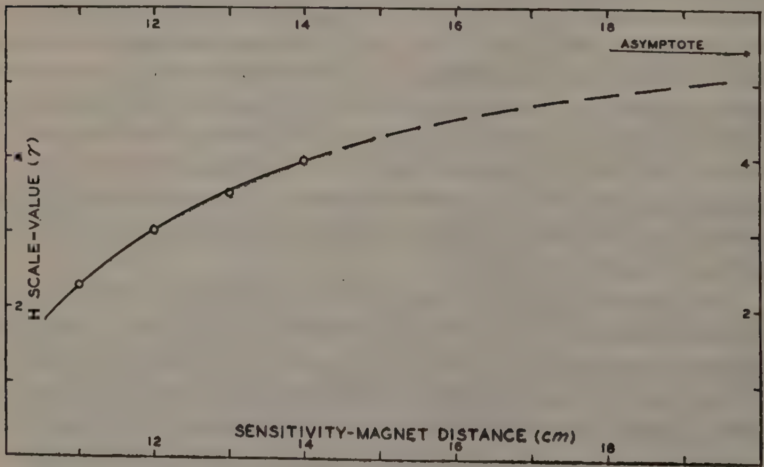

FIG. 1

Variation in H-sensitivity with ordinate is usually determined from the regular scale-value observations covering a long period but in the present investigation it seemed quite desirable to determine this factor in a short time. The recording drum is of such dimensions that only small range in ordinate is available. Accordingly a flat screen was attached to the front of the recording box and strips of bromide paper attached to this screen. The deflections were recorded directly upon this paper without the use of the cylindrical lens. In the computations the ordinates were reduced to drum for the sake of uniformity. A series of observations was made in which the undeflected ordinate was altered over the maximum possible range by rotation of the torsion-head but with field constant (except for the natural fluctuations of H). A second series was made in which the torsion-head was left unchanged but the field was altered by means of an auxiliary magnet and the desired ordinate thereby obtained. The results of these observations are shown in Table 2 and indicate that the change with ordinate is practically the same in both cases. Following this comparison a longer series was made by changing the ordinate with a deflector. The final results are shown in Table 3 and plotted in

TABLE 2—*Variation of horizontal-intensity scale-value with ordinate for Toepfer variometer X at San Juan, Porto Rico, January 26, 1928*

Quantity	Fixed head, changing H			Constant H, changing head			
True ordinate, h, in mm	−145.9	−22.2	+127.5	+167.5	−150.8	+17.7	+128.7
$2u'$ in mm	148.0	121.9	105.8	102.0	151.0	118.0	105.0
ϵ in gammas	2.119	2.592	2.964	3.075	2.077	2.658	2.959
$d\epsilon/dh$		.0031				.0031	

TABLE 3—*Variation of horizontal-intensity scale-value as determined by changing ordinate with a deflector for Toepfer variometer X at San Juan, Porto Rico, January 28, 1928*

Ordinate, h, in mm	−276.0	−156.0	−37.8	+75.6	+166.0	+278.0
$2u'$ in mm	199.7	164.7	141.1	121.3	109.4	101.5
ϵ in gammas	1.74	2.11	2.46	2.87	3.18	3.43
$d\epsilon/dh$ for range of magnetogram			.0031			

Figure 2. The ordinates were reduced to drum by applying a factor equal to the ratio of perpendicular distances from variometer-lens to drum and from variometer-lens to screen plus a correction for the cylindrical lens. The results show that the factor

changes with ordinate and whether it is a result of asymmetry in the field or in torsion itself or of other causes is immaterial as it is the ordinate on the straight scale which is used in practice. For the range of the magnetogram it is sufficiently accurate to use the mean value for the ordinates covering the magnetogram.

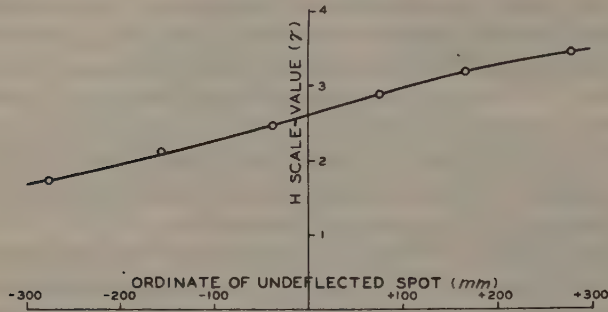

FIG. 2

THE VERTICAL-INTENSITY VARIOMETER

Originally the Coast and Geodetic Survey vertical-intensity recording magnets were equipped with steel pivots resting in agate-cups. On three of these variometers the agate cups have been replaced by agate-planes fixed in the same horizontal plane.

In spite of great care in lowering the recording magnet, it is believed that the greatest damage to the pivots arises when they are first made to carry the weight. Some sample pivots were obtained from the General Electric Company and from the Weston Electrical Instrument Corporation for experimental use. In the tests described in this paper and made at the Cheltenham Magnetic Observatory the Weston pivots were used in all cases as the others seemed to be too small. In a letter from the General Electric Company, it was stated that the pressure on the pivot-points (as supplied by them) when subjected to a load of 20 grams, the mass of the recording magnet, would be of the order of 20 tons per square inch. It is not surprising that pivots of softer material are permanently distorted under such conditions.

Variometer No. 20 was equipped with agate-planes rigidly mounted upon adjustable plates and these planes were carefully adjusted to the same horizontal plane, the adjustment being checked by a test-plate which gave wide interference-fringes on both plates at the same time, with the test-plate level and the instrumental axis vertical. In the second series the agate-planes

were adjusted only approximately to the same plane, that is, they were simply adjusted with a small level. With the Weston pivots and the carefully adjusted planes it was possible to obtain periods as great as 20 seconds, whereas the greatest period obtainable with the old pivots was 9 seconds. A period of 20 seconds represents a scale-value of approximately 0.5 gamma per millimeter.

The first results obtained with these pivots in connection with the agate-planes seems to indicate that they may be quite satisfactory for use in routine operation at fairly high sensitivities. Sensitivities were tested by deflections, with deflector in the meridian, with deflector in the prime-vertical, by oscillations and by weights. There seems to be some indication that the sensitivity changes with ordinate but as this question has not been settled definitely it will be left for a later discussion.

Variation of sensivity with center of gravity. In order to determine the possible range of scale-values with the Weston pivots a complete series of observations was made with the sensitivity counterpoise in various positions from the lowest to the highest. The counterpoise was first set at its highest position and the pivots adjusted so that the variometer was just unstable for this position, when the system was resting on the agate-planes. The recording magnet was then removed from the variometer and suspended by a silk fiber in a small magnet-house in such a manner that it would oscillate about a vertical axis through the pivot-points. The magnet-house was equipped with a telescope and scale and was oriented in such a manner that scale-readings could be observed as reflected from the recording magnet-mirror. The period of the magnet oscillating under the H-component of the Earth's field was then determined very accurately. Values of the period for highest and lowest positions of the counterpoise were determined and the mean used in the computations which follow. An inertia-ring was then balanced on the magnet and its period redetermined. From these observations the moment of inertia, K_1, and the magnetic moment, M, were computed from equation (2). The moment of inertia of the recording magnet is given by

$$K_1 = K_2 T_1^2/(T_2^2 - T_1^2)$$

and the magnetic moment by

$$M = \pi^2 K_1/T_1^2 H$$

Combining these equations,

$$M = \pi^2 K_2/H(T_2^2 - T_1^2) \qquad (2)$$

in which K_2 = the moment of inertia of the ring, T_1 = the period of the magnet alone, T_2 = the period of the magnet and ring together, and $H = 18750$ gammas. The magnetic moment was also determined by the deflection of the H-component of the Adie variometer and computed from the equation

$$M = r^3 (2u') \epsilon_h / 4 \times 10^5 \qquad (3)$$

in which r = the deflection-distance, $2u'$ = the double deflection in millimeters on the magnetogram, and ϵ_h = the scale-value of the variometer recording magnet. The results from these two methods agree very closely giving a value of $M = 314$ at 20° C. This value was used later in the determination of scale-value by weights.

The Z-magnet was then placed in the variometer and with the counterpoise at its lowest position, its period was determined by means of a stop-watch and deflections were made at a distance of 25 centimeters. The counterpoise was then raised by steps of five turns up to the position of instability, observations of oscillations and deflections being made at each step. Deflections of the D-variometer were made at the beginning and end of the series. The value of the distribution-coefficient P, determined later, was taken as 129. The observed period was corrected for damping although decay-curves were not recorded or observed in this series. The damping factors were obtained from a later series. For the shorter periods or very low sensitivities the damping may be neglected but

TABLE 4—*Variation in sensitivity with center of gravity for Schulze vertical-intensity variometer 20 at Cheltenham Maryland, March 7, 1928*
($P_n = 170$, $\log f/(f-h) = .0131$, $r = 25.0$ cm, $2u = 22.8$ mm)

Counterpoise setting in turns	$2u'$	T_d	$\log T^2{}_f$	ϵ_d	ϵ_o	$K_o = \frac{S}{T^2}$	$\epsilon = \frac{1}{K_o T^2{}_f}$
	mm	s					
0	18.9	2.41	0.7625	8.66	8.08	.01994	8.49
5	20.8	2.51	0.7978	7.87	7.45	.02024	7.82
10	23.5	2.71	0.8640	6.97	6.38	.01963	6.72
15	27.8	2.88	0.9165	5.89	5.65	.02057	5.95
20	32.0	3.14	0.9913	5.12	4.75	.01994	5.01
25	40.1	3.51	1.0872	4.08	3.79	.02003	4.02
30	51.3	3.92	1.1822	3.19	3.03	.02059	3.23
35	73.5	4.68	1.3338	2.23	2.12	.02081	2.28
40	123.0	5.99	1.5426	1.33	1.28	.02153	1.41
45	256.9	10.10	......	0.64	....	......	....
50	Unstable	.....	......	....	....	......	....
		Mean value K_o				.02036	

is appreciable for the longer periods or high sensitivities. The results of the observations are given in Table 4, in which $2u'$ = the

double deflection of the Z-spot with the deflector at 25 cm, T_d= the observed period of the recording magnet, log $T^2{}_f$=the double log of the period corrected for damping, ϵ_d=the scale-value computed from deflections, ϵ_o=the scale-value computed from oscillations, K_o=the ratio of sensitivity $(1/\epsilon_d=S)$ to $T^2{}_f$, and ϵ=adjusted scale value from oscillations$=1/(K_oT^2{}_f)$. Within the working range of the variometer the scale-value seems to vary almost directly with the position of the counterpoise. With a larger poise the departure from a direct proportion would be more marked. The relation between scale-value and position of the counterpoise is shown in Figure 3, also the relation between sensitivity, $1/\epsilon$,

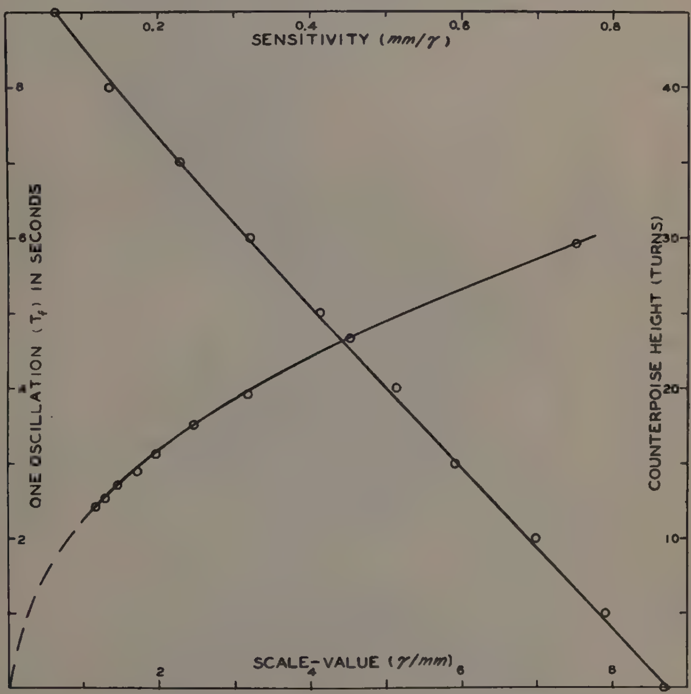

FIG. 3

and period. The relations between scale-value and period and between scale-value and $1/T^2{}_f$ are shown in Figure 4.

Computation of scale-values. The scale-value by deflections was computed from a formula similar to equation (1), except that a correction is necessary for distribution.[3] For convenience the equation is repeated

[3]D. L. HAZARD, Directions for magnetic measurements, p. 106, second edition (1921).

$$\epsilon_z = (2u/2u')\ (H/2R)\ (f/(f-h))\ (1+P/r^2)$$

in which $2u'$ is double deflection in mm of the Z-spot and P is distribution-coefficient. P is a function of the relative sizes of the recording magnet and deflector and also of the orientation of these two magnets. The scale-value from oscillations was computed also from the following equation

$$\epsilon_0 = H\, T^2_h\, \theta_r / T^2_f \tag{5}$$

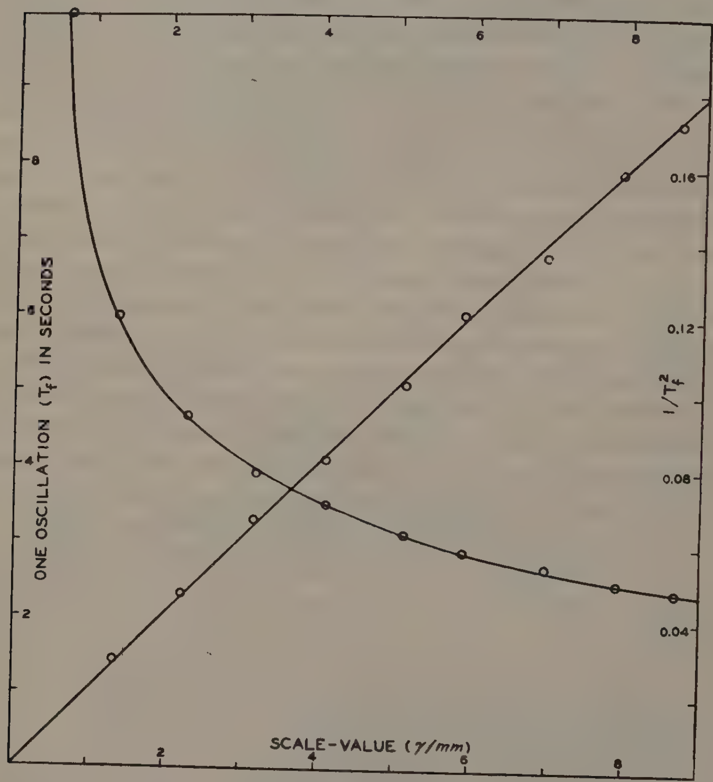

Fig. 4

in which T_h = the period of the magnet oscillating under the force H, that is with the axis through the pivots vertical = 3.357 sec., T_f = the period of the recording magnet while resting on the pivots and oriented in the magnetic meridian, θ_r = the value in radians of one mm. on the magnetogram = $1/2R$ = 1/4488 radian, and ϵ_0 = the scale-value.[4]

In the above equation it is necessary to correct the observed

[4] Geo. Hartnell, *Terr. Mag.*, v. 24, 1919 (55).

period for damping. That is, if T_d is the observed period and λ the log decrement, the free period T_f is given by the equation

$$T^2_f = T^2_d \, (1/(1+\lambda^2/\pi^2) \qquad (6)$$

In a later series of observations with changing position of counterpoise and periods, decay-curves were recorded photographically so that the damping coefficients might be determined. For the decay-curves the intensity of the light was increased so that the turning points at least were well defined. The recording drum rotates but once in 24 hours so that the advance of the mag-

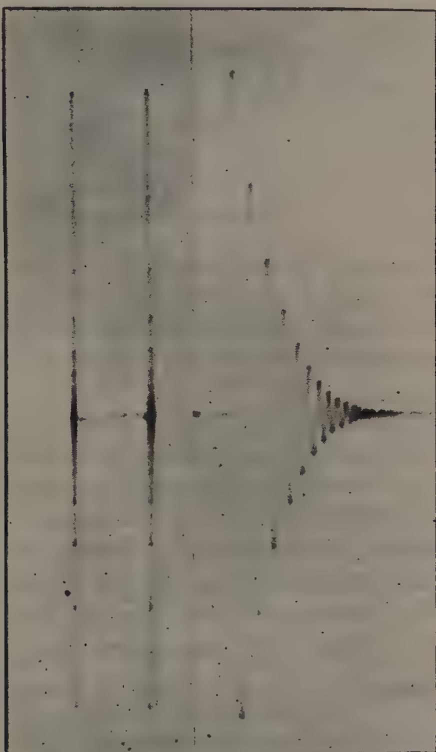

FIG. 5

netogram during the interval required for the recording magnet to come to rest from a large displacement is very small and the successive swings overlap but the turning points may be distinguished quite easily and scaled from the magnetogram. An attempt was made to rotate the drum by hand and the result was fairly successful. Sample decay-curves with the slower and more rapid motions are shown in Figure 5. There is no particular advantage for

present purposes in using the more rapid motion, in fact, the decay-curves in which the swings overlap may be measured more conveniently. Table 5 gives the results of this second series in which

TABLE 5—*Variation in sensitivity with center of gravity for Schulze vertical-intensity variometer 20 at Cheltenham, Maryland, April 20, 1928*

(P_n=129, P_e=−4, r=23.0 cm, $2u$=30.41 mm)

Counterpoise setting in turns	$2u'$(N)	$2u'$(E)	T_d	log $T^2 f$	ϵ'_n	ϵ'_e	ϵ_d	ϵ_o	K_o
0	27.15	21.75	2.48	0.7874	7.90	7.87	7.88	7.72	.0207
4	31.0	24.8	2.66	0.8480	6.92	6.90	6.91	6.71	.0205
8	34.0	26.35	2.73	0.8704	6.31	6.49	6.40	6.38	.0210
12	36.9	29.6	2.86	0.9105	5.81	5.78	5.80	5.81	.0212
16	46.85	36.8	3.16	0.9969	4.58	4.65	4.62	4.76	.0218
20	52.7	43.1	3.45	1.0724	4.07	3.97	4.02	4.00	.0211
24	65.0	52.2	3.78	1.1512	3.30	3.28	3.29	3.34	.0215
Mean value of K_o									.0211

the counterpoise was advanced by steps of four turns and with the recording magnet equipped with a different set of pivots. Also the agate-planes were simply adjusted to the same horizontal plane by means of a small level and without testing for fringes as in the first case.

After the completion of the series of sensitivity-tests described above the sensitivity-poise was set for a scale-value of about 5.40 gammas per millimeter and observations made at values of r equal to 19, 21, 23, 25, 27, and 29 cm, for the purpose of determining the value of the distribution-coefficient P. Deflections were made on the D-variometer at the above distances and on the north and east sides of the Z-variometer at the same distances, deflector north end up and north end down. The scale-values computed from these

TABLE 6—*Vertical-intensity scale-value for Schulze variometer 20 at Cheltenham, Maryland, March 7, 1928*

(P_n=170, P_e=144)

r in cm	19	21	23	25	27	29
$2u$ in mm	52.6	38.8	29.5	22.8	18.2	14.9
$2u'(N)$ in mm	81.5	57.7	40.9	31.0	23.8	18.8
$2u'$(E) in mm	62.8	45.3	33.7	26.0	20.4	16.6
ϵ'_n in gammas	3.64	3.80	4.07	4.15	4.32	4.48
ϵ'_e in gammas	4.73	4.84	4.94	4.95	5.04	5.07
ϵ_n in gammas	5.36	5.26	5.38	5.32	5.38	5.38
ϵ_e in gammas	5.31	5.32	5.35	5.30	5.34	5.33

Resulting mean values: ϵ_n, 5.33 gammas; ϵ_e, 5.32 gammas.

tests are shown in Table 6 but without regard for distribution-coefficient. The values for the north position are smaller than those for the east position but may be reconciled by the adoption of proper values for the distribution-coefficients P_e and P_n. In order to utilize all of the observations and obtain most satisfactory values for these coefficients, the problem was arranged in the form of 12 equations of the following form

$$\epsilon=\epsilon'_n\,(1+P_n/r^2) \qquad (7)$$

and

$$\epsilon=\epsilon'_e\,(1+P_e/r^2) \qquad (8)$$

in which ϵ=the true scale-value, ϵ'_n=the scale-value, north position (distribution neglected), ϵ'_e=the scale-value, east position (distribution neglected), r=the deflection-distance, P_n=the distribution-coefficient for the north position, and P_e=the distribution coefficient for the east position. The equations were transformed to the following form for use:

$$\epsilon-P_n\,\epsilon'_n/r^2-\epsilon'_n=0 \qquad (9)$$

and

$$\epsilon-P_e\,\epsilon'_e/r^2-\epsilon'_e=0 \qquad (10)$$

The data for the least-square adjustment are given in Table 7.

TABLE 7—*Data for least-square adjustment to determine distribution-coefficients P_n and P_e*

r	r^2	ϵ'_n	ϵ'_e	ϵ'_n/r^2	ϵ'_e/r^2
19	361	3.64	4.73	.0101	.0131
21	441	3.80	4.84	.0086	.0110
23	529	4.07	4.94	.0077	.0093
25	625	4.15	4.95	.0066	.0079
27	729	4.32	5.04	.0059	.0069
29	841	4.48	5.07	.0053	.0060

The resulting normal equations are

$$12.0\;x-4.42\;y-5.42\;z-54.03=0 \qquad (11)$$
$$-4.42\;x-3.42\;y\qquad +17.74=0 \qquad (12)$$
$$-5.42\;x\qquad +5.25\;z+26.54=0 \qquad (13)$$

in which $\epsilon=x$, $P_n=100\,x$, and $P_e=100\,z$. The solution gives $x=$ 5.33, $P_n=170$, and $P_e=44$. The scale-values were recomputed using these values and are given in the last two lines of Table 6. The results in Table 4 were obtained using $P_n=170$.

As pointed out by Hazard, on page 32 of "Directions for Magnetic Measurements," small errors of observation in deflections will have large effects on the accuracy of the value of P. It is for this reason that in each of the series in these tests a value of P was derived from the series itself. The value derived from a series for deflections on one side of the Z-variometer differs materially from that derived from a complete set, that is, from deflections on both sides.

Finally a series of deflections was made at various distances but with deflector in the four usual positions, that is, on both sides of the variometer, and the series was concluded by making deflections with a large bar-magnet at about two meters distance and attached to the wall of the variation-room in the necessary positions, one side only. The results of these tests are given in Table 8, using

TABLE 8—*Vertical-intensity scale-value for Schulze variometer 20 at Cheltenham, Maryland, April 21, 1928*

($P_n=129$, $P_e=-4$)

r	$2u$	$2u'$(N)	$2u'$(E)	ϵ'_n	ϵ'_e	ϵ_n	ϵ_e	ϵ_s
cm	*mm*	*mm*	*mm*	γ	γ	γ	γ	γ
21	40.0	84.0	64.45	2.70	3.52	3.49	3.49	3.49
23	30.2	61.0	48.0	2.81	3.57	3.49	3.54	3.52
25	23.3	45.6	37.5	2.90	3.52	3.49	3.50	3.50
27	18.7	34.8	30.0	3.04	3.53	3.58	3.51	3.54
29	14.8	27.7	24.2	3.03	3.47	3.49	3.45	3.47
							Mean	3.50
192	28.7	46.5	....	....	....	....	....	3.50

$P_n=129$ and $P_e=-4$, the values having been obtained from the series by least-square adjustment as before. The scale-value computed from the deflections by the large deflector at the great distance agrees very closely with the mean for the series and no correction has been made for distribution for this particular observation. It seems to indicate that the resultant field at the center of the variometer is very uniform and indicates also that the method of applying distribution-coefficients is correct within working limits.

SCALE-VALUE BY WEIGHTS

While engaged in this investigation of pivots it occurred to the writer that it might be possible to determine sensitivity by weights, that is, by the application of definite small masses in defi-

nite positions on the recording magnet of the Z-variometer and noting the deflections produced. An attempt was made, first, to provide the variometer with short arms one cm in length extending along the axis of the magnet and as nearly in the plane of the pivots as possible. A one-tenth-milligram rider was made and applied first on one arm and then on the other with the variometer at its lowest sensitivity but owing to the extreme difficulty of manipulation of the small rider, as well as the necessity of removing the recording magnet from the case each time a change was made, the results obtained in this manner were very unsatisfactory. Also the sensitivity of the system was altered by the addition of the small mass and apparently there was a slight flexure of the arms used. Accordingly, a phosphor-bronze-wire coil with one end extending beyond the coil about 7mm was made. The inner diameter of this coil was such that the coil, or "flag" as it will be called hereafter, fitted accurately over the counterpoise stem of the recording magnet. Records were made with the flag extending first north and then south along the axis of the recording magnet. Even with the lowest sensitivity obtainable without altering the pivots the deflections were quite large. After the deflections were completed the flag was removed and its moment about its axis of rotation was carefully determined by A. T. Pienkowsky of the U. S. Bureau of Standards. This moment was found to be 0.00205 ± 4 per cent gram-centimeters. From the trace-amplitude, the dimensions of the optical system, and the above moment the scale-value was computed from equation (16). The scale-value was also determined by oscillation and deflection and the results by the three methods are given in Table 9.

The relations between the gravity-moment of the flag in the different positions and the other moments involved are given by the following equations

$$(HM+lmg)\ \theta_1 = lmg\ \theta_o - ZM + pgd \tag{14}$$

$$(HM+lmg)\ \theta_2 = lmg\ \theta_o - ZM - pgd \tag{15}$$

in which H = the horizontal intensity of the Earth's field, Z = the vertical intensity of the Earth's field, M = the magnetic moment of the recording magnet, l = the distance from the axis of rotation to the center of gravity of the magnet, m = the mass of the recording magnet (19.3 grams), g = gravity, θ_1 = the deflection-angle north in radians, θ_2 = the deflection-angle south in radians, θ_0 = the deflection-angle in radians without the mass added, p = the added

mass (north or south side), d = the distance from axis of rotation to the point of application of the mass, θ_r = the value in radians of one millimeter on magnetogram, and n = the double deflection in millimeters corresponding to $\theta_1 - \theta_2$. As used in this test, $2\ p\ d$ = .0041 gram-centimeters. Subtracting (15) from (14) and multiplying both sides by θ_r/M gives

$$\left(\frac{H\,M + l\,m\,g}{M}\right)\theta_r = \left(\frac{.0041\ g}{M\,(\theta_1 - \theta_2)}\right)\theta_r$$

But [5] the first part of this equation is equal to the scale-value, ϵ_w, and for small angles

$$\theta_r/(\theta_1 - \theta_2) = 1/n \text{ and}$$
$$\epsilon_w = .0041\ g/M\ n \qquad (16)$$

TABLE 9—*Comparison of scale-values as determined by three methods for Schulze vertical-intensity variometer 20 at Cheltenham, Maryland, May 1, 1928, after change in adjustment of sensitivity*

Method	Observed data	Values	
Weights	Double deflection for flag north and then south from ten observations, n in mm	117.2	
	Gravity-moment doubled, $2pgd$	(.0041) (980)	
	Magnetic moment of recording magnet, M in c. g. s. units	314	
	Scale-value ϵ_w in gammas from equation (16)	10.9	
Oscillations	Time T_d in seconds of one oscillation for flag east	2.06	
	Scale-value ϵ_o in gammas from equation (5)	11.1	
Deflections	Deflection-distance, r in cm	21.0	23.0
	Double deflection $2u'$ in mm for flag east	20.0	15 1
	Double deflection on D-variometer, $2u$ in mm	39.4	30.4
	Scale-value ϵ_d in gammas from equation (4)	11.1	11.3

Owing to the very large deflection in the method by weights and the comparatively small deflection by method of deflections, as well as the uncertainty of sensitivity with ordinate, it is not surprising that there is some disagreement in the results given in Table 9. It is to be noted that the sensitivity was reduced to a minimum for these tests as the deflection produced by the flag was quite large even though the flag itself was very small.

[5] GEO. HARTNELL, *Terr. Mag.*, v. 24, 1919 (54).

U. S. COAST AND GEODETIC SURVEY,
WASHINGTON, D. C,
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ON EARTH-CURRENT OBSERVATIONS AT WATHEROO MAGNETIC OBSERVATORY, 1924-1927

By O. H. Gish and W. J. Rooney

Abstract—The earth-current measuring system at Watheroo Magnetic Observatory provides for a number of independent records of both components of potential gradient, a feature which has proven helpful in detecting and locating the source of disturbing effects. The results obtained during the four-year period, 1924-1927, are discussed. The diurnal-variation curve of the northward component has a mean range of 1.14 millivolts per kilometer with maxima at $17^h.5$ and $12^h.5$ and minima at 8^h and $17^h.5$ (120th east meridian mean time). The records resemble those obtained in the northern hemisphere at Berlin and Ebro except that the curve is inverted and smaller in amplitude. The reversal in the direction of current-flow points to a symmetrical distribution of earth-currents with reference to the equator. The small amplitudes can be explained on the basis of the unusually high conductivity of the region about Watheroo. No regular change was observed in the mean diurnal-variation for individual years. The range of the diurnal-variation curve varies with season from 0.71 millivolts per kilometer in June (midwinter) to 2.06 millivolts per kilometer in October (late spring), and the morning minimum and midday maximum shift forward with increasing height of Sun. The amplitudes of the three principal harmonics vary with season in a similar manner, indicating a single predominating cause for seasonal variation in the normal activity. The eastward component is extremely small at Watheroo; its diurnal-variation curve has, in general, a double period and a mean range of less than 0.15 millivolt per kilometer.

Four years of registration have been completed on the earth-current measuring system at the Watheroo Magnetic Observatory, which is 120 miles north of Perth, Western Australia, in latitude 30° 19′.1 south and longitude 115° 52′.6 east. The continuity of recording has been good, and sufficient data to be representative have been secured for all months except September 1927, during which a defect in the potentiometer-recorder rendered the results inconclusive. The salient features of the results for the four-year period are summarized in the following pages.

The earth-current lines, as originally laid out,[1] consisted of a rectangular system with a common point *O*, connected to the recording station by underground conduit, and two points (*M* and *N* and *P* and *Q*, respectively) on each line, distributed at intervals of one mile (1.6 km). The line *OPQ* extends due north and *OMN* due east from the common point. Points *Q* and *N* are connected to the recording station by aerial lines, while both aerial lines and underground connections in conduit are provided between the recorder and points *P* and *M*. Two electrodes were installed at each of the five points with the switching arrangements such that either one of any pair may be used separately or both may be used in parallel. Hence, for the first time it has been possible to secure a large num-

[1] O. H. Gish, General description of the earth-current measuring system at Watheroo Magnetic Observatory. *Terr. Mag.*, v. 28, 1923 (89-108).

ber of simultaneous independent records of both components of the potential gradient, so taken as to provide for direct comparison of the results obtained (*a*) with different lengths of line, (*b*) with different electrodes, and (*c*) with different types of line-construction. This arrangement has proven especially valuable in detecting and locating the source of disturbing effects.

The installation of the lines was completed in 1923 under the supervision of G. R. Wait, observer-in-charge, with the assistance of observers J. S. Shearer and J. E. I. Cairns: Mr. Cairns with the succeeding members of the Observatory staff, namely, H. F. Johnston, observer-in-charge, and observers O. W. Torreson and F. W. Wood, has continued the observations. Registration was begun near the close of 1923.

In recording, various combinations of electrodes and lines were used at different times to localize the causes of any differences noted in the results. To avoid the repetition of such tedious descriptions as "the north-south line, two miles long, with one electrode at the north end and both electrodes in parallel at the south end, using aerial connections" the following nomenclature will be used to describe the several combinations. Where both electrodes at a point were used in parallel the electrode is referred to simply by the letter designating the point. Where a single one of the pair was used, the designation O', O'', F', P'', etc., distinguishes between them. For points P and M the subscripts a or u are used to indicate whether the connection was made by aerial or underground line.

The original electrodes constituted a temporary installation in sites selected solely for their relative positions. The first features brought out by the threefold comparison already referred to were (1) the necessity of having longer east-west lines because of the small values obtained for the eastward component and (2) the desirability of obtaining uniform electrode-environment and optimum conditions as to the resistivity of the soil about the electrodes. Hence, during 1926 and 1927, a second electrode-installation was made in which the eastward line was extended and all the electrodes were placed in like clay-soil. During the last half of 1927 the two systems were compared by operating them in alternate half-months. In referring to the newer electrodes the subscript x is used. The common point, O_x, of the new system is located 100 meters due east of O. On a line due north from it are P_x and Q_x, 1.25 and 2.13 miles, respectively, from O_x. Due east of O_x are N_x and R, 2.05 and 6.19 miles, respectively, from O_x.

From the standpoint of earth-current study, as has been pointed out by a number of investigators, the absolute values of the recorded potentials are more or less meaningless, since they represent chiefly electrode-effects. For example, at Watheroo during March, 1926, electrode O was negative with respect to P', the mean difference between them being 28.2 millivolts, while for the same period the average potential of O with reference to P'' was +41.6 millivolts. Similar differences in magnitude and sign of the potential recorded between adjacent electrodes and the common one were found at other times and confirm the conclusion that most of the potential measured is due to electrochemical action at the electrodes. For this reason only the diurnal and shorter-period variations are considered in examining the records, correction being made for the slow aperiodic changes which occur in the so-called "constant" part of the potential.

GENERAL TYPE OF DIURNAL VARIATION

Mean curves of the diurnal variation for the four-year period, 1924 to 1927, are shown in Figure 1. The data used in their construction were recorded on the two-mile lines OQ and ON except for the last half of 1927 when the records from O''_xQ_x and $O''_xP'_x$ (2.13 and 1.25 miles long, respectively) were combined with those from OQ for the northward component, and records from O_xR (6.19

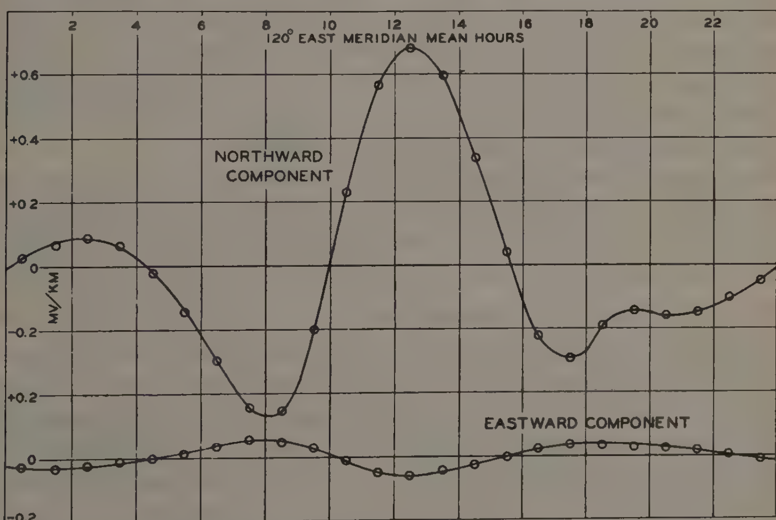

FIG. 1—Diurnal variation of earth-current potential-gradient at Watheroo, Western Australia (Curves show average departure of the mean hourly values from the mean of day for the four-year period 1924-1927)

miles long) were used as well as those from *ON* for the eastward component. Positive values indicate a current directed northward or eastward. All classes of days are included in the means here used. Omission of the most disturbed days at Watheroo results in little change in the diurnal-variation characteristics.

The range of the northward curve is 1.14 mv per km, with a principal minimum at $8^h\ 00^m$ and a principal maximum at about $12^h\ 30^m$. A secondary maximum occurs at about $2^h\ 30^m$ and a secondary minimum at $17^h\ 30^m$. Following this afternoon minimum the curve is somewhat irregular but typically so, a kink of similar character between 18^h and 22^h always being found in the records for the individual months.

In general appearance the curve for the *northward component* resembles those obtained in the northern hemisphere at Berlin and Ebro except that it is inverted. Since Watheroo is situated well down in the southern hemisphere this points to a certain symmetry in the distribution of earth-currents with reference to the equator. If the sign of the departures were in all cases taken with reference to the equator, the curves would agree in sign as well as in shape. Aside from this reversal in direction, the chief differences between the Watheroo results and those from the other sites are (1) in amplitude, which is considerably less than that at Ebro, and (2) in relative magnitues of the forenoon and afternoon minima (considering the Watheroo curve inverted), the latter appearing as decidedly the principal one at Berlin and Ebro while at Watheroo it is generally of an appreciably smaller amplitude, which only rarely exceeds the morning minimum and then only slightly and for short periods.

The first of these differences, that in amplitude, is capable of explanation on the basis of the conductivity of the surrounding regions. If earth-currents are to be considered as induced currents circulating in paths of great dimensions, the magnitude of the currents will depend on the resistance of their paths as a whole, while the potential gradient as determined at a given locality will be proportional to the resistance of the portion of the paths in the immediate vicinity of the measurements. Earth-resistivity surveys[2] made in the vicinity of the Watheroo and Ebro observatories in 1926 have shown Watheroo to be a region of unusually high conductivity. Owing to the presence there near the surface of a stratum of salt-impregnated clay with a resistivity less than 500 ohms per

[2]W. J. ROONEY and O. H. GISH, Results of earth-resistivity surveys near Watheroo, W. A., and at Ebro, Spain. *Terr. Mag.*, v. 32, 1927 (49-63).

centimeter cube, the average resistivity of the region to depths of some 300 meters was found to be comparable to that of a fresh-water area. The Ebro survey indicated more normal resistivity for the earth material there, the values running more than a magnitude higher about that observatory. Hence the difference in the magnitude of the potentials recorded at the two places may be attributed chiefly to difference in resistivity and the results do not, therefore, indicate any marked difference in the corresponding earth-current densities. Because of the fact that the Berlin records are reported in arbitrary rather than standard units of potential gradient only a qualitative comparison can be made with the results of those observations. The difference in the relative amplitudes of the forenoon and afternoon minima cannot be so readily explained.

The curve for the *eastward component* shown in Figure 1 is remarkable chiefly for its small range, less than 0.15 mv per km. It is a double-period curve with maxima corresponding fairly well in time to the principal minima of the northward curve and minima which are reached at about the same time as the maxima of the northward curve. Owing to the smallness of the eastward component the records obtained with the original installation were often unsatisfactory, in that the three independent and simultaneous records for this component showed clearly that extraneous effects at the individual electrodes frequently masked the true diurnal variation. This feature will be treated at greater length later in this paper when discussing electrode-effects. The general features of the mean curve for the whole period, however, are borne out by the more reliable records from the individual lines and by the records obtained with the second electrode-system. With this new system the eastward component has been much more consistent than previously and quite obviously free from extraneous electrode-effects, and the monthly curves agree very well with the mean curve shown in Figure 1.

DIURNAL VARIATION IN INDIVIDUAL YEARS

In Figure 2 are shown annual curves of diurnal variation for the years 1924, 1925, 1926, and 1927. The curves have not been smoothed but the agreement of the individual curves one with the other and with the mean curve in Figure 1 is quite fair for the northward component. The variation in amplitude and phase is small and there appears to be no regular change from year to year. If, as there is evidence from the results of observations in other places,[3]

[3] L. A. BAUER, *Terr. Mag.*, v. 27, 1922 (22).

variations in the amplitude of the diurnal curves corresponding to variations in sunspot-frequency exist, they have evidently been masked by electrode-effects or other uncertanties in the recorded data. The data for the eastward component are far less satisfactory and the curves for the individual years are not in good agreement, that for 1927 departing the most from the mean curve in Figure 1. In fact, it would appear that the close agreement of the mean curve with the more reliable records for short periods is somewhat fortuitous, and due to the averaging out of the extraneous effects over the four-year period.

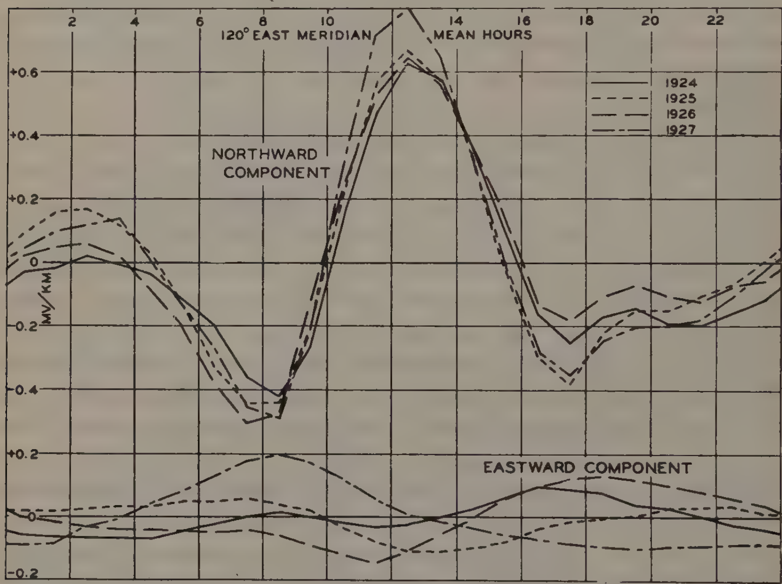

FIG. 2—Diurnal variation of earth-current potential-gradient at Watheroo, Western Australia, for the individual years 1924, 1925, 1926, and 1927

SEASONAL CHANGES

Tables 1 and 2 give the hourly means of the northward and eastward component respectively for the four-year period by months. Because of the minuteness of the eastward component at Watheroo and the consequent uncertainties introduced in its measurement by electrode-effects, the data in Table 2 are not considered suitable for exact analysis. About the only conclusion which can be reached from them is that this component is very small and that the diurnal-variation curve has in general a double period. At the conclusion of registration for a full year with the new electrode-

system more reliable information regarding the eastward component promises to be available.

The data for the northward component are much more consistent as will be seen by reference to Table 3 which shows the results of harmonic analyses of the diurnal-variation data as given in Figures 1 and 2 and in Table 1. The range of the diurnal variation of the northward component, as shown in Table 1, is found to run from 0.71 mv per km in June (midwinter) to 2.06 mv per km in October (late spring). Reference to Table 3 shows that the second harmonic or twelve-hour wave predominates throughout the year, its amplitude ranging from 0.19 mv per km in midwinter to 0.53 in spring. Next in order of magnitude on the average is the third harmonic with an amplitude about 60 per cent that of the second and practically the same variation with season. During the summer months the amplitude of the first harmonic (24-hour wave) is ap-

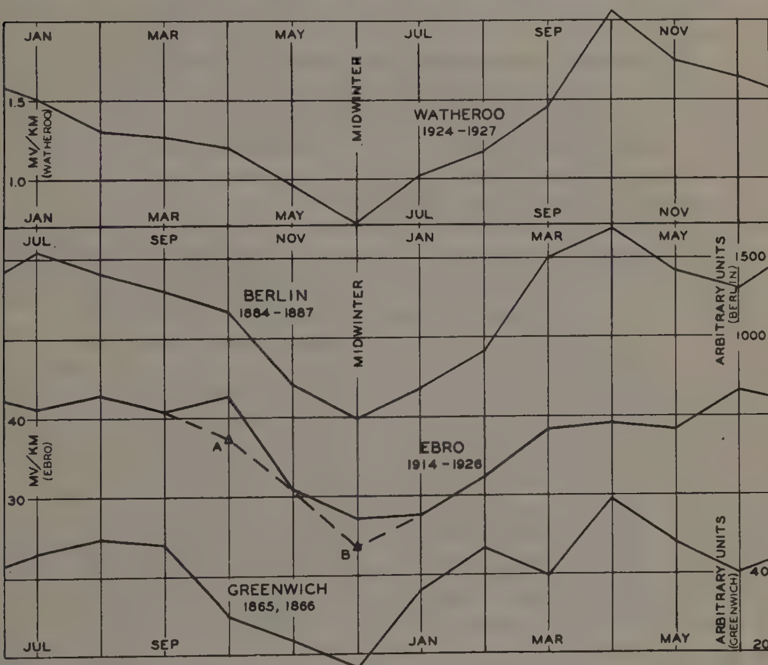

FIG. 3—Seasonal variation in range of monthly mean diurnal-variation curves for the northward component of earth-current potential-gradient at Watheroo, Berlin, Ebro, and Greenwich (For the Ebro curve the points *A* and *B* are the means omitting the months of October 1917 and December 1925 because the range in both these months is far in excess of that for corresponding months in the remaining 11 years)

TABLE 1—*Average monthly diurnal-variation in millivolts per kilometer of earth-current northward component at Watheroo, 1924-1927*
(Tabular values are average values for successive periods of one hour as indicated 120th east meridian mean time; values greater than mean of day are indicated by + sign, northward component being considered as positive)

Time	Four-year average for												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
h h													
0– 1	+0.01	+0.04	+0.07	+0.09	+0.12	+0.14	+0.06	0.00	−0.02	−0.04	−0.05	+0.01	+0.03
1– 2	+0.04	+0.08	+0.20	+0.15	+0.16	+0.19	+0.07	+0.02	0.00	+0.02	0.00	+0.06	+0.07
2– 3	+0.03	+0.14	+0.23	+0.21	+0.16	+0.12	+0.08	+0.08	+0.05	+0.03	+0.02	+0.02	+0.09
3– 4	+0.03	+0.21	+0.29	+0.10	+0.07	+0.09	+0.04	+0.04	+0.05	+0.03	+0.06	−0.04	+0.07
4– 5	−0.16	+0.10	+0.19	+0.07	+0.01	0.00	+0.02	+0.01	+0.03	−0.08	−0.22	−0.20	−0.02
5– 6	−0.39	−0.06	+0.02	−0.11	−0.06	−0.06	+0.02	−0.01	−0.07	−0.19	−0.42	−0.46	−0.15
6– 7	−0.58	−0.36	−0.23	−0.27	−0.10	−0.02	−0.01	−0.01	−0.18	−0.55	−0.70	−0.64	−0.30
7– 8	−0.52	−0.51	−0.49	−0.48	−0.27	−0.05	−0.07	−0.23	−0.55	−0.83	−0.70	−0.53	−0.44
8– 9	−0.21	−0.38	−0.46	−0.49	−0.51	−0.27	−0.42	−0.57	−0.66	−0.76	−0.43	−0.22	−0.45
9–10	+0.27	+0.03	−0.03	−0.16	−0.39	−0.38	−0.52	−0.56	−0.50	−0.32	+0.03	+0.21	−0.19
10–11	+0.80	+0.54	+0.51	+0.21	−0.10	−0.19	−0.26	−0.29	−0.12	+0.37	+0.55	+0.80	+0.23
11–12	+0.93	+0.78	+0.78	+0.57	+0.27	+0.09	+0.11	+0.10	+0.36	+0.91	+0.96	+1.01	+0.57
12–13	+0.81	+0.74	+0.71	+0.72	+0.43	+0.19	+0.34	+0.47	+0.74	+1.23	+1.05	+0.91	+0.69
13–14	+0.54	+0.57	+0.45	+0.63	+0.46	+0.33	+0.50	+0.60	+0.81	+1.07	+0.83	+0.59	+0.60
14–15	+0.16	+0.26	+0.10	+0.20	+0.37	+0.33	+0.49	+0.60	+0.59	+0.64	+0.39	+0.18	+0.35
15–16	−0.19	−0.09	−0.21	−0.03	+0.17	+0.16	+0.20	+0.34	+0.35	+0.10	−0.04	−0.18	+0.05
16–17	−0.33	−0.32	−0.37	−0.19	−0.12	−0.13	−0.11	−0.01	+0.02	−0.28	−0.26	−0.36	−0.21
17–18	−0.30	−0.44	−0.37	−0.26	−0.25	−0.17	−0.17	−0.19	−0.17	−0.35	−0.29	−0.36	−0.29
18–19	−0.15	−0.34	−0.29	−0.23	−0.13	−0.10	−0.08	−0.06	−0.14	−0.21	−0.16	−0.23	−0.18
19–20	−0.11	−0.24	−0.29	−0.23	−0.12	−0.04	−0.05	−0.04	−0.09	−0.17	−0.04	−0.10	−0.13
20–21	−0.16	−0.24	−0.24	−0.19	−0.13	−0.06	−0.09	−0.11	−0.14	−0.25	−0.09	−0.12	−0.16
21–22	−0.15	−0.23	−0.17	−0.15	−0.10	−0.06	−0.08	−0.11	−0.16	−0.24	−0.14	−0.14	−0.15
22–23	−0.23	−0.14	−0.11	−0.12	+0.02	+0.02	−0.04	−0.05	−0.14	−0.13	−0.12	−0.12	−0.10
23–24	−0.10	−0.09	−0.01	−0.08	+0.06	+0.05	−0.02	−0.04	−0.08	−0.13	−0.09	−0.09	−0.05
Range	1.51	1.30	1.27	1.21	0.97	0.71	1.02	1.17	1.47	2.06	1.75	1.65	1.14
Time[a] of	*h*	*h*	*h*	*h*	*h*	*h*	*h*	*h*	*h*	*h*	*h*	*h*	*h*
A. M. min.	6.8	7.5	7.8	8.2	8.8	9.2	9.2	9.0	8.5	7.8	7.2	6.8	8.0
Noon max.	11.5	11.8	11.8	12.5	13.2	14.0	14.0	13.8	13.2	12.8	12.2	11.8	12.5
P. M. min.	17−	17+	17−	17+	17.5	17+	17+	17.5	17.5	17+	17+	17+	17.5

[a] Times are given to nearest quarter-hour.

TABLE 2—*Average monthly diurnal-variation in millivolts per kilometer of earth-current eastward component at Watheroo, 1924-1927*
(Tabular values are average values for successive periods of one hour as indicated 120th east meridian mean time; values greater than mean of day are indicated by + sign, eastward component being considered as positive)

Time	Four-year average for												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
h h													
0– 1	+0.10	+0.07	−0.04	−0.03	−0.09	−0.09	−0.11	−0.10	−0.12	−0.12	0.00	+0.15	−0.03
1– 2	+0.11	+0.05	−0.06	−0.04	−0.07	−0.08	−0.11	−0.11	−0.10	−0.11	−0.04	+0.15	−0.03
2– 3	+0.13	+0.06	−0.05	−0.04	−0.04	−0.06	−0.11	−0.10	−0.09	−0.10	−0.06	+0.15	−0.03
3– 4	+0.11	+0.04	−0.07	−0.04	+0.01	−0.04	−0.09	−0.08	−0.07	−0.09	−0.07	+0.15	−0.02
4– 5	+0.14	+0.06	−0.09	−0.04	+0.04	−0.02	−0.08	−0.07	−0.06	−0.07	−0.08	+0.16	−0.01
5– 6	+0.15	+0.04	−0.06	−0.02	+0.08	0.00	−0.07	−0.04	−0.03	−0.04	−0.08	+0.16	+0.01
6– 7	+0.19	+0.05	−0.04	+0.01	+0.10	+0.02	−0.05	−0.04	0.00	+0.01	−0.07	+0.16	+0.03
7– 8	+0.19	+0.08	−0.04	+0.04	+0.13	+0.03	−0.03	0.00	+0.03	+0.08	−0.05	+0.14	+0.05
8– 9	+0.09	+0.03	−0.04	+0.06	+0.16	+0.09	+0.02	+0.06	+0.08	+0.11	−0.09	0.00	+0.04
9–10	−0.01	−0.04	−0.07	+0.05	+0.18	+0.11	+0.07	+0.09	+0.11	+0.13	−0.16	−0.12	+0.03
10–11	−0.13	−0.14	−0.12	0.00	+0.16	+0.12	+0.10	+0.12	+0.11	+0.10	−0.20	−0.25	−0.01
11–12	−0.22	−0.20	−0.12	−0.02	+0.12	+0.10	+0.08	+0.11	+0.11	+0.07	−0.22	−0.36	−0.05
12–13	−0.25	−0.21	−0.10	−0.02	+0.08	+0.08	+0.10	+0.09	+0.08	+0.06	−0.18	−0.37	−0.06
13–14	−0.26	−0.19	−0.06	−0.01	+0.05	+0.07	+0.10	+0.10	+0.08	+0.04	−0.10	−0.33	−0.04
14–15	−0.21	−0.14	+0.01	+0.02	−0.01	+0.03	+0.08	+0.07	+0.10	+0.05	+0.02	−0.26	−0.02
15–16	−0.15	−0.04	+0.05	+0.04	−0.02	−0.01	+0.07	+0.06	+0.09	+0.08	+0.11	−0.18	+0.01
16–17	−0.11	−0.02	+0.12	+0.05	−0.03	−0.02	+0.08	+0.05	+0.06	+0.07	+0.17	−0.11	+0.03
17–18	−0.07	+0.02	+0.15	+0.06	−0.07	−0.03	+0.05	+0.04	+0.02	+0.05	+0.21	−0.03	+0.03
18–19	−0.03	+0.06	+0.16	+0.05	−0.11	−0.03	+0.03	0.00	−0.01	+0.01	+0.22	+0.03	+0.03
19–20	−0.01	+0.07	+0.12	+0.02	−0.14	−0.04	+0.01	−0.01	−0.04	−0.01	+0.20	+0.07	+0.02
20–21	+0.03	+0.06	+0.13	−0.01	−0.13	−0.04	−0.01	−0.03	−0.05	−0.04	+0.18	+0.13	+0.02
21–22	+0.05	+0.10	+0.09	−0.03	−0.13	−0.05	−0.02	−0.06	−0.06	−0.08	+0.14	+0.16	+0.01
22–23	+0.09	+0.08	+0.07	−0.04	−0.13	−0.06	−0.04	−0.08	−0.10	−0.08	+0.11	+0.17	0.00
23–24	+0.08	+0.07	+0.06	−0.05	−0.12	−0.06	−0.06	−0.09	−0.12	−0.11	+0.06	+0.18	−0.01
Range	0.45	0.31	0.28	0.11	0.32	0.21	0.21	0.22	0.23	0.21	0.44	0.55	0.11
Time[a] of	*h*	*h*	*h*	*h*	*h*	*h*	*h*	*h*	*h*	*h*	*h*	*h*	*h*
A. M. min.	(3.5)	(3.5)	(4.5)	0	....	0.5	1.5	1.5	23.5	0.5	(4.5)	(2.0)	(1.5)
A. M. max.	7.0	7.5	(7.0)	8.5	9.5	10.5	13.0	11.0	10.5	9.0	(7.5)	(6.5)	8.0
P. M. min.	13.0	12.5	11.0	12.5	19.5	....	....	....	(13.0)	(13.5)	11.5	12.5	12.5
P. M. max.	(22.5)	21.0	18.0	17.5	....	....	(16.5)	....	(15.0)	(15.5)	18.5	23.5	(18.0)

[a] Times are given to nearest quarter-hour, and where features are not well defined times are enclosed in parentheses.

proximately equal to that of the third, but in midwinter it becomes very small, the ratio of minimum to maximum amplitude for this harmonic being about one-ninth as against one-third for the second and third.

The variation in range of the diurnal variation with season is shown graphically in the uppermost curve in Figure 3. This curve, which is constructed from the mean records for the four-year period, has a sharply defined minimum in June and an equally pronounced maximum in October. The records for the individual years agree quite closely with the four-year mean, all indicating pronounced extremes in midwinter and late spring with a tendency to a secondary maximum near the autumnal equinox.

Beneath the Watheroo curve in Figure 3, the data from three sites in the northern hemisphere have been similarly plotted for comparison, with a phase-shift of six months to bring out the seasonal agreement. The Berlin curve, constructed from the mean data for the five-year period 1884-1887, shows the same midwinter minimum and spring maximum. It is somewhat more irregular in the summer months. The Ebro curve, which shows the average range of the individual monthly diurnal-variation curves for the twelve years 1914-1926, is considerably less regular than the Watheroo or Berlin curve, particularly during the summer months. The midwinter minimum, while less pronounced, is definite, but the spring maximum is quite decidedly less prominent. The Ebro data show markedly less regularity in the range for the same months of different years than to the Watheroo records. The dotted section of the curve, for instance, shows how the mean curve would be changed and the winter minimum accentuated by omitting from the average the records for the months of October 1917 and December 1925, both of which months had ranges far in excess of those for the corresponding months of the remaining eleven years. The curve for Greenwich, which covers a period of less than two years, 1865-1866, is also more irregular than the Watheroo curve but the spring maximum and the winter minimum, particularly the latter are, nevertheless, very well defined.

Referring again to Tables 1 and 3, the time of day at which the morning minimum and midday maximum of the diurnal-variation curve occur is found to vary considerably with time of year. Both are earliest at about the time of the summer solstice (December, January) and latest at the winter solstice (June, July), the extreme difference in their times of occurrence being in

excess of two and one-half hours. Curiously, however, the evening minimum does not show a corresponding shift in time with season, its position varying certainly not more than one-half hour either way from 17^h. The tendency of the morning minimum and mid-day maximum to shift forward with increasing height of Sun has been pointed out by Weinstein and others but these investigators report a corresponding shift towards sunset in the position of the afternoon minimum.

TABLE 3—*Harmonic analyses of diurnal variations of earth-current potential-gradients at Watheroo, 1924-1927*

Component	Period	Amplitudes				Phase-angles			
		c_1	c_2	c_3	c_4	ϕ_1	ϕ_2	ϕ_3	ϕ_4
		mv/km	*mv/km*	*mv/km*	*mv/km*	°	°	°	°
Northward	Year 1924	0.179	0.282	0.172	0.070	246	35	223	27
	Year 1925	0.192	0.321	0.179	0.042	227	42	239	37
	Year 1926	0.108	0.358	0.205	0.053	258	46	236	24
	Year 1927	0.169	0.381	0.231	0.076	262	45	236	46
	4-year average 1924-1927	0.159	0.333	0.195	0.048	245	43	234	34
	4-year average								
	Jan	0.270	0.400	0.277	0.037	259	70	274	90
	Feb	0.207	0.395	0.246	0.065	281	49	248	126
	Mar	0.164	0.366	0.262	0.096	305	49	251	89
	Apr	0.127	0.354	0.205	0.070	260	40	241	48
	May	0.061	0.283	0.147	0.073	198	26	200	14
	Jun	0.036	0.188	0.100	0.087	144	18	175	339
	Jul	0.076	0.232	0.173	0.110	199	8	181	351
	Aug	0.139	0.291	0.204	0.100	200	6	183	353
	Sep	0.216	0.375	0.230	0.080	216	17	205	21
	Oct	0.324	0.531	0.339	0.108	236	42	232	44
	Nov	0.311	0.495	0.299	0.037	237	59	254	45
	Dec	0.278	0.451	0.276	0.033	255	72	269	78
Eastward	4-year average 1924-1927	0.0027	0.0375	0.0170	0.0068	165	222	61	222

The similar manner in which the three principal harmonics vary in phase and amplitude throughout the year, as shown in Table 3, points to a single predominating cause for the normal activity in earth-currents, the term "normal activity" here being used to distinguish the more regular changes in diurnal variation from the violent disturbances of relatively short duration such as are found to occur during magnetic storms. The manner in which the changes in phase and amplitude take place shows an indisputable relation between this normal activity and the position of the Sun.

The probable effect of changes in the conductivity of the Earth's crust on the normal activity has been considered by a number of investigators but the Watheroo records together with the results of the earth-resistivity survey already referred to show that the change in amplitude can be due only in small part, if at all, to such a cause, since the variation of resistivity with season was found to be extremely small where any appreciable depth of soil is considered, and, moreover, the periods of maximum and minimum conductivity do not correspond either directly or inversely to the times of extremes in amplitude.

Further discussion concerning sources of error and conclusions drawn from the earth-current data will be published in the next number of the JOURNAL.

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REVIEWS AND ABSTRACTS

(See also pages 94, 100, 104, 109)

PALAZZO, LUIGI: *Risultati di una esplorazione magnetica nei territori del Giuba e dell' Uebi Scebeli.* Roma, Rend. Acc. Naz. Lincei, Classe di Scienze fisiche, matematiche e naturali, v. 5, ser. 6, fasc. 12, 1927 (933-940).

The present note contains a preliminary résumé of the results obtained by the author during a magnetic exploratory expedition in the Italian colonies in East Africa (Jubaland Province and Southern Somaliland) in connection with the astronomical party sent thither for observing the total solar eclipse of January 14, 1926. The object was to secure observations at inland points and thus extend the magnetic map of the country which had previously only included a few stations along the coast.

In all, observations of the three magnetic elements were obtained at 17 points, of which five were repeat-stations and thus yielded information regarding the secular change. The earlier results of these five stations were reduced to the epoch 1910.0 and the later ones to 1926.0. A comparison of the resultant values gave a mean secular variation for the 16-year period as follows: $D=-1°\,42'$; $I=-1°\,29'$; $H=-340\gamma$. Assuming that the variation over the period under examination was uniform, the values of the mean annual secular-variation would be: $\Delta D=-6'.4$; $\Delta I=-5'.6$; $\Delta H=-21\gamma$ (declination being west and inclination south, minus sign denoting numerical decrease in the element).

With the aid of the above values five other stations previously occupied, but not reoccupied, were likewise reduced to the epoch 1926.0, making a total of 22 stations on the basis of which isomagnetic charts of the territory were constructed which will be published later.

From a general consideration of the magnetic survey in Italian Somaliland, the author feels warranted in asserting that, in the region investigated, there is no important anomaly in the distribution of the magnetic elements and, accordingly, no indication, at least at present, of the existence of subterranean mineral deposits such as would be likely to be disclosed by a magnetic reconnaissance.

An attempt was made to derive from the recent determinations in Somaliland a formula for expressing the relation between the inclination and latitude along the 44th meridian, which is almost central between Jubaland and Uebi Scebeli. The formula is simply linear

$$I=21°.91-2.32\phi$$

where I and ϕ are expressed in degrees and decimals of degrees and I is regarded as positive although south. For $\phi=0$, the formula gives $I=21°.91$ or $21°\,55'$ as the value of the magnetic inclination at the intersection of the geographical equator with the 44th meridian. H. D. HARRADON

SOME OBSERVATIONS UPON TELLURIC CURRENTS AND THEIR APPLICATION TO ELECTRICAL PROSPECTING

By E. G. Leonardon

The application of the potentiometric methods of electrical prospecting to the search for ore-bodies or to the study of structural and stratigraphical problems requires the measurement of very minute differences of potential.

The firm with which the writer is connected has thus explored in the course of its consulting practice hundreds of square miles; the magnitude of the individual electrical measurements obtained amounted ordinarily to only a few millivolts. This kind of research, aside from its precise commercial purpose, involves necessarily the possibility of making a series of investigations upon the electrical phenomena occurring in the Earth's crust, namely, the earth-currents and the electro-capillarity of the soil.

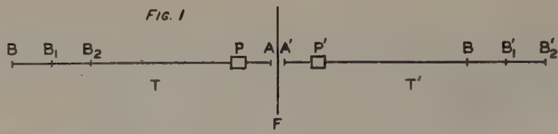
The present article is concerned with the recording of some results obtained by comparing the intensities of the Earth's currents occurring on the two sides of a fault. The observations were made only occasionally and constitute, indeed, a very unimportant contribution to the study of these currents. However, the problem of the electrical phenomena in the soil is so complex and still so incompletely studied, that the publication of every experiment regarding this question may present some interest.

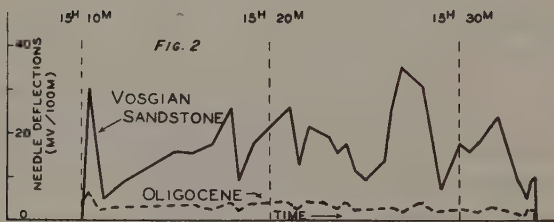
The measurements described hereafter were made in 1921, by the author, under the direction of Professor Conrad Schlumberger, near Lobsann (Alsace) on the Rhine fault. They can be briefly explained as follows:

Suppose that the two insulated electrical lines, AB and $A'B'$ of equal length (100 meters, for instance) each including one potentiometer P and P', are disposed on the same straight line with A and A' only a few feet apart as indicated on Figure 1. Connect AB, $A'B'$ with the ground. We will admit that if the soil is homogeneous the earth-current is a large phenomenon, and that for all the region studied its density is constant (tubes of force cylindrical and lines of current parallel). If this is the case, the indications furnished by the two potentiometers at the same time will be identical. On the contrary, if the rocks underlying AB are more resistant than those underlying $A'B'$, the difference of potential measured by P will be greater than the one measured by P'. This difference in the readings taken with the bases AB and $A'B'$ will

be the indication of a heterogeneity. In certain cases, this simple process will permit one to locate this heterogeneity and to appreciate its importance.

Fig. 1





For instance, F is a vertical fault bringing into contact two formations T and T' of resistivities R and R'. We will dispose the lines AB and $A'B'$ so that AB lies entirely on the formation T and $A'B'$ on the formation T', with the line $BAA'B'$ perpendicular to the fault. In such a case, if $\triangle V$ and $\triangle V'$ are the differences of potential measured with the apparatus we will have the relation

$$\triangle V/\triangle V' = R/R'$$

Under the assumptions previously indicated, this relation is true whatever be the direction of the telluric current. When this current is prependicular to the fault-plane, the application of Ohm's law to a tube of current (cylinder perpendicular to the fault-plane) makes the formula evident. If the earth-current is oblique to the fault the vector "density of current" can be separated into two components, one of which is parallel and the other perpendicular to the fault-plane. We can consider separately the two fields thus defined. The latter one brings up again the case of a current perpendicular to the fault-plane, for which the law is exact.

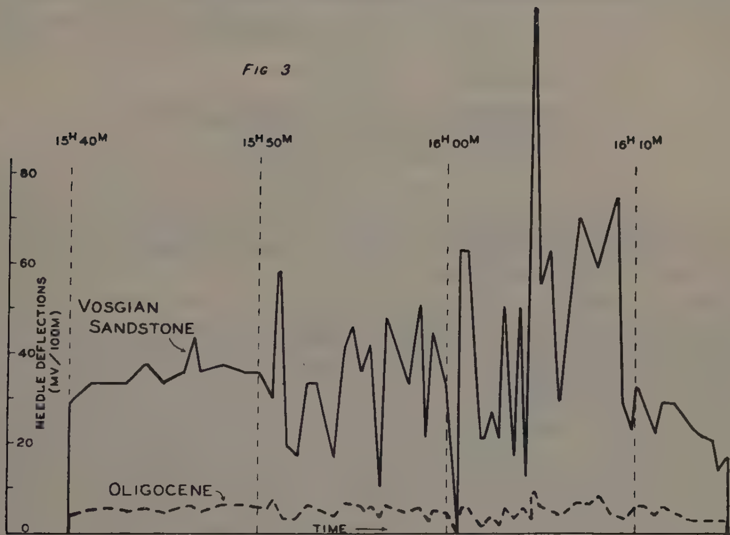
The experiment, then, gives immediately the ratio of the resistivities of the two formations. It is easy to verify, by comparing several pulsations of the earth-current, that this ratio is constant. If necessary, an average value can be calculated.

To apply this procedure to the location of a fault hidden under a cover, the system of lines AB, $A'B'$ and apparatus P and P' is translated in a direction approximately perpendicular to the sup-

posed fault. It occupies successively the position BB', $B_1B'_1$; $B_2B'_2$, etc. For each station, the ratio of drop of potential $\triangle V/\triangle V'$ is measured. As long as this ratio is not different from one, the soil is homogeneous. When the system crosses the fault the ratio differs from unity and when the fault is entirely behind it, the ratio becomes again equal to one. The position of the fault is given by the station for which the ratio differs most widely from unity.

This experiment was tried on the Rhine fault, at a place where its location was very accurately known by previous electrical work. The accompanying graphs (Figs. 2 and 3) represent the

FIG 3



differences of potential simultaneously recorded with AB on one compartment of the fault and $A'B'$ on the other one. The differentiation between the formations (Vosgian sandstones on the northwest side, Oligocene marls on the southeast side) is very pronounced and is marked by a corresponding variation in the amplitude of the pulsation measured on the two compartments.

We will also mention, in the domain of observations which can be made on telluric currents, the fact that the conductive ore-bodies seem to have a sensible influence in their distribution. These deposits attract the currents flowing in the ground, whether or not such currents are artificial or natural. As a result, in the vicinity of the extremities of the conducting masses an abnormal density of current is observed in the surrounding rocks themselves.

The differences of potential which occur locally may then be considerably amplified in favorable cases and attain a magnitude which is 20 or 30 times the average value observed nearby on barren ground. Under these conditions, a telluric pulsation which is not noticeable at a distance of 400-600 feet from an ore-body, gives rise just at its extremities to differences of potential attaining some millivolts, and which can be measured without any serious error.

All the above considerations refer only to the study of natural telluric currents. It is evident that the potentiometric methods are also quite adapted to the study of the currents arising from industrial power-stations or traction-systems, and that investigations along this line could be carried out with great ease and speed.

REVIEWS AND ABSTRACTS

(See also pages 90, 100, 104, 109)

K. F. WASSERFALL: *On periodic variations in terrestrial magnetism. Studies based upon photographic records from the polar station Gjöahavn.* (Geofys. Pub., Oslo, v. 5, No. 3, 1927, 33 pp.)

The investigations are based principally upon the daily mean values of the horizontal component of the Earth's magnetic field as derived from the magnetograms obtained during November 1, 1903, to June 1, 1905, at Amundsen's polar station, Gjöahavn (latitude, 68° 37′ north; longitude, 95° 55′ west). The method of investigation, given in considerable detail, depends on *smoothed* means, that is the means of any selected number of values, such as 5, 7, 10, or 14, advancing through the series day by day, or hour by hour according to the interval of the time-argument. The means so formed presumably eliminate waves of the corresponding periods 5, 7, 10, etc., and the differences between these means and the values of the original series corresponding to the same instant probably show the wave of the period more clearly, if it actually exists, than the original series though the amplitude may appear too small. Even if there is no period exactly equal to the number of values chosen to form the means, the method may yet reveal a wave of nearly the same period.

Comparisons were made with temperature-data recorded at Gjöahavn and Oslo, treated in the same manner and also with Wolfer sunspot-numbers.

The author finds periods of 3.3 days average duration for horizontal intensity. H, and for sunspot-numbers, R, and 4.8 days for temperature, T, at both Gjöahavn and Oslo. He also finds indications of a sporadic period between 10 and 11 days both in horizontal intensity and temperature at Gjöahavn. In searching for periods corresponding to the rotation of the Sun he takes the mean latitude (south and north) for the spots during 1904 as $\pm 17°$ for which he gives the period about 27.3 days. His H-curves give 28 days and his T-curves give 28. 5. Examination for periods of 14 days indicate periods of 14.3 and 14.1 for H and T, respectively.

After the elimination of 28-day waves the resulting curve does not show the smooth annual wave that was expected but reveals fairly regular undulations of 41 days and also of 70 days. The author, however, concludes that these may not be the result of outside agencies but rather the rhythmical coincidence of shorter waves, though the 70-day period appears to be confirmed by Potsdam data for H extending over the years 1905–1917.

W. J. PETERS

LATEST ANNUAL VALUES OF THE MAGNETIC ELEMENTS AT OBSERVATORIES[a]

COMPILED BY J. A. FLEMING

Observatory	Latitude	Longitude	Year	Declination (D)	Inclination (I)	Intensity Hor. (H)	Intensity Ver. (Z)
	° ′	° ′		° ′	° ′	c. g. s.	c. g. s.
Matochkin Shar	73 16 N	56 24 E	1923[b]	20 30.6 E	80 02.8 N	.09517	.54232
			1924	20 37.5 E	80 05.4 N	.09491	.54326
Sodankylä.....	67 22 N	26 39 E	1923[c]	1 30.6 E	75 42.6 N	.12529	.49189
			1924[d]	1 41.2 E	75 45.4 N	.12490	.49204
			1925[d]	1 52.5 E	75 48.4 N	.12440	.49186
Lerwick.......	60 08 N	1 11W	1924[e]	15 30.6W	72 35.7 N	.14642	.46708
			1925[e]	15 17.7W	72 37.2 N	.14621	.46712
Pavlovsk (Sloutzk)......	59 41 N	30 29 E	1925	3 25.3 E	71 27.1 N	.15770	.47000
			1926	3 34.7 E	71 31.5 N	.15715	.47035
Sitka.........	57 03 N	135 20W	1926[d]	30 25.2 E	74 22.9 N	.15501	.55447
			1927[d]	30 23.5 E	74 22.6 N	.15491	.55394
Katharinenburg (Swerdlovsk)	56 50 N	60 38 E	1925	11 01.0 E	72 03.0 N	.16513	.50974
			1926	11 01.0 E	72 06.2 N	.16443	.51033
Rude Skov....	55 51 N	12 27 E	1924	7 10.4W	69 05.1 N	.17053	.44621
			1925	6 57.7W	69 07.2 N	.17025	.44631
Kazan (Saimistsche)	55 50 N	48 51 E	1925[f]	8 57.0 E	70 12.2 N	.17260	.47951
			1926	9 03.3 E	70 18.3 N	.17191	.48028
Eskdalemuir...	55 19 N	3 12W	1924	16 01.2W	69 38.7 N	.16673	.44938
			1925	15 48.4W	69 39.3 N	.16665	.44943
Meanook......	54 37 N	113 20W	1924	27 17.7 E	77 53.7 N	.12866[g]	.59984[g]
			1925[h]	27 10.7 E	77 53.8 N	.12852	.59934
Stonyhurst....	53 51 N	2 28W	1926[i]	14 39.7W	68 44.6 N	.17240	.44316
			1927[i]	14 26.5W	68 43.5 N	.17231	.44251
Irkutsk (Zouy).	52 28 N	104 02 E	1925	0 45.5 E	71 15.6 N	.19070	.56212
			1926	0 42.9 E	71 16.8 N	.19025	.56141

[a] See tables for previous years in *Terr. Mag.*, v. 4, 135; v. 5, 128; v. 8, 7; v. 12, 175; v. 16, 209; v. 20, 131; v. 22, 169; v. 23, 191; v. 25, 179; v. 26, 147; v. 27, 157; v. 29, 149; v. 31, 27; and v. 32, 27; some annual values already published in the tables for the previous years are repeated to show secular-change rates.

[b] Values are means for three months, October to December, and supersede those previously given in *Terr. Mag.*

[c] Final values superseding those previously given in *Terr. Mag.*

[d] Preliminary values.

[e] Means from absolute values only.

[f] Beginning with 1925 the values are from magnetograms for all days.

[g] No values for March.

[h] No values for September.

[i] Means for five international quiet days except for *I*, which is mean of absolute values.

Observatory	Latitude	Longitude	Year	Declination (D)	Inclination (I)	Intensity Hor. (H)	Intensity Ver. (Z)
	° ′	° ′		° ′	° ′	c. g. s.	c. g. s.
Potsdam	52 23 N	13 04 E	1926[c]	6 20.6W	66 42.6 N	.18503	.42982
			1927[c]	6 09.2W	66 44.7 N	.18490	.43006
Seddin	52 17 N	13 01 E	1924[c]	6 46.8W	66 35.0 N	.18589	.42922
			1925[c]	6 34.7W	66 36.8 N	.18570	.42938
			1926[d]	6 21.9W	66 39.5 N	.18541	.42967
Swider	52 07 N	21 15 E	1923[c]	3 09.5W	66 39 N	.18672	.43251
			1924[c]	2 58.0W	66 42 N	.18645	.43294
DeBilt	52 06 N	5 11 E	1925	10 25.4W	66 53.5 N	.18359	.43026
			1926	10 13.1W	66 55.5 N	.18337	.43040
Valencia	51 56 N	10 15W	1924[e]	18 34.9W	68 00.6 N	.17854	.44213
			1925[e]	18 22.4W	68 00.0 N	.17849	.44177
Bochum	51 29 N	7 14 E	1924	9 36.6W	......	......	......
			1925	9 25.9W	......	......	......
Kew	51 28 N	0 19W	1923	13 57.3W	66 57.0 N	.18394	.43230
			1924	13 45.1W	66 56.5 N	.18392	.43205
Greenwich	51 28 N	0 00	1924[c]	13 22.8W	66 51.6 N	.18426	.43112
			1925[c]	13 09.9W	66 51.4 N	.18414	.43080
Abinger	51 11 N	0 23W	1925[ii]	13 22.7W	66 35.1 N	.18597	.42946
			1926	13 10.4W	66 36.3 N	.18581	.42947
			1927	12 58.4W	66 36.2 N	.18575	.42932
Uccle	50 48 N	4 21 E	1918	12 10.0W	66 02.6 N	......	......
			1919	12 00.6W	66 02.9 N	......	......
			1920	11 50.6W	66 04.1 N	......	......
			1921	11 39.0W	66 03.7 N	......	......
			1922	11 28.2W	66 03.5 N	......	......
			1923	11 15.1W	......	......	......
			1924	11 03.8W	......	......	......
			1925	10 52.7W	......	......	......
Prague	50 05 N	14 25 E	1922	6 12.1W	......	......	......
			1923	6 00.4W	......	......	......
			1924	5 48.1W	......	......	......
			1925	5 34.9W	......	......	......
Val Joyeux	48 49 N	2 01 E	1924	12 07.9W	64 38.9 N	.19663	.41501
			1925	11 55.8W	64 38.7 N	.19659	.41485
Munich	48 09 N	11 37 E	1923	7 29.1W	......	......	......
			1924	7 17.5W	......	......	......
			1925	7 06.7W	......	......	......
O'Gyalla (Pesth)	47 53 N	18 12 E	1917	5 29.9W	......	.20941	......
			1918	5 21.9W	......	.20917	......

[ii] Means for 10 months, February to November.

Observatory	Latitude	Longitude	Year	Declination (D)	Inclination (I)	Intensity Hor. (H)	Intensity Ver. (Z)
	° ′	° ′		° ′	° ′	c. g. s.	c. g. s.
Nantes	47 15 N	1 34W	1924[j]	13 11.6W	63 41.6 N	.20240	.40940
			1925[j]	12 59.6W	63 39.0 N	.20234	.40850
Odessa	46 26 N	30 46 E	1922	2 01.3W	63 08.0 N	......	......
			1923	1 53.1W	63 11.5 N	.21272	.42098
			1924	1 44.6W	63 15.1 N	.21246	.42154
			1925	1 36.4W	63 18.9 N	.21213	.42206
Pola	44 52 N	13 51 E	1921[k]	6 38.6W	60 10.3 N[l]	.22094	.38537[l]
			1922	6 28.0W	60 12.8 N[l]	.22090	.38591[l]
Agincourt	43 47 N	79 16W	1925	7 09.7W	74 44.2 N	.15728[c]	.57628
			1926	7 13.4W	74 44.6 N	.15692	.57527
Karsani	41 50 N	44 42 E	1926	4 12.3E	58 03.0 N	.24694	.39595
Capodimonte	40 52 N	14 15 E	1922	6 25.7W	57 02.6 N	.23705	.36563
Ebro (Tortosa)	40 49 N	0 31 E	1925	11 08.8W	57 28.4 N	.23367	.36642
			1926	10 59.1W	57 27.7 N	.23362	.36617
Coimbra	40 12 N	8 25W	1924	14 45.6W	58 14.1 N	.23128	.37353
			1925	14 38.2W	58 13.9 N	.23143	.37368
			1926	14 28.5W	58 12.4 N	.23144	.37337
Cheltenham	38 44 N	76 50W	1926[d]	6 42.8W	71 02.2 N	.18809	.54740
			1927[d]	6 45.8W	71 02.5 N	.18770	.54640
San Miguel	37 46 N	25 39W	1921[m]	19 15.9W	60 20.8 N	.23132	.40621
			1922[m]	19 10.8W	60 17.0 N	.23189	.40630
			1923[m]	19 05.5W	60 11.9 N	.23204	.40514
			1924[m]	19 01.1W	60 07.4 N	.23245	.40459
			1925[m]	18 56.5W	60 03.0 N	.23256	.40378
San Fernando	36 28 N	6 12W	1925	13 15.1W	53 40.0 N[n]	.25032	......
			1926	13 07.7W	53 38.6 N[n]	.25020	......
Kakioka[o]	36 14 N	140 11 E	1915	5 15.6W	49 31.3 N	.29752	.34863
			1916	5 17.6W	49 31.7 N	.29743	.34859
Tsingtau	36 04 N	120 19 E	1919	4 09.9W	52 07.4 N	.30812	.39613
			1920	4 12.9W	52 07.0 N	.30817	.39610
Tucson	32 15 N	110 50W	1926[d]	13 44.6 E	59 32.3 N	.26632	.45280
			1927[d]	13 44.1 E	59 32.5 N	.26585	.45210

[j] Electric-car disturbance-effects, especially marked in Z.

[k] For four months, September to December, only.

[l] Magnetograph values for hours 2, 6, 10, 14, 18, and 22; other values for all hours.

[m] D's are from magnetograms, other values are means of absolute determinations.

[n] These values are from absolute observations with dip circle, the individual results showing irregularities.

[o] The observatory records from January, 1917, to August, 1923, were lost in the fire at Tokyo following the earthquake of September 1, 1923.

Observatory	Latitude	Longitude	Year	Declination (D)	Inclination (I)	Intensity Hor. (H)	Intensity Ver. (Z)
	° ′	° ′		° ′	° ′	c. g. s.	c. g. s.
Lukiapang.....	31 19 N	121 02 E	1921	3 24.0 E	45 30.5 N	.33189	.33784
			1922	3 25.1 E	45 30.5 N	.33204	.33799
Dehra Dun....	30 19 N	78 03 E	1924	1 34.6 E	45 17.0 N	.32943	.33270
			1925	1 30.5 E	45 21.0 N	.32948	.33353
Helwan.......	29 52 N	31 20 E	1921	1 15.9W	41 15.4 N	.29947	.26269
			1922	1 07.8W	41 17.9 N	.29957	.26316
			1923	1 00.3W	41 20.2 N	.29973	.26366
Hongkong[p].... (new hut)...	22 18 N	114 10 E	1926[e]	0 29.6W	30 42.4 N	.37323	.22167
			1927[e]	0 31.7W	30 39.9 N	.37376	.22161
Honolulu......	21 19 N	158 04W	1926[d]	10 03.0 E	39 28.3 N	.28658	.23600
			1927[d]	10 04.2 E	39 28.9 N	.28634	.23589
Teoloyucan....	19 45 N	99 11W	1922[e]	9 09.9 E	46 30.7 N	.32160(?)	.33903(?)
			1923[e]	9 14.0 E	46 25.5 N	.31548	.33158
			1924[e]	9 14.4 E	46 28.5 N	.31551	.33219
			1925[e]	9 14.6 E	46 28.1 N	.31652	.33321
Toungoo......	18 56 N	96 27 E	1921	0 26.8W	23 07.0 N	.39132	.16704
			1922	0 29.7W	23 07.2 N	.39156	.16717
			1923[q]	0 31.9W	23 06 1 N	.39207	.16725
Alibag........	18 38 N	72 52 E	1923	0 07.9 E	25 08.4 N	.37017	.17376
			1924	0 04.6 E	25 12.9 N	.37061	.17453
Vieques[r]......	18 09 N	65 27W	1923	4 08.3W	51 38.1 N	.27629	.34902
			1924[r]	4 14.9W	51 41.9 N	.27570	.34908
Antipolo......	14 36 N	121 10 E	1923	0 31.7 E	16 00.0 N	.38174	.10941
			1924	0 31.5 E	15 59.7 N	.38201	.10950
Kodaikanal....	10 14 N	77 28 E	1921	1 54.2W	4 38.5 N	.37832	.03071
			1922	1 58.7W	4 40.1 N	.37878	.03093
			1923[q]	2 00.7W	4 41.3 N	.37950	.03112
Batavia-Buitenzorg...	6 11 S	106 49 E	1925[e]	0 53.1 E	32 07.6 S	.36834	.23130
			1926[e]	0 51.7 E	32 11.5 S	.36832	.23187

[p] Registration it was hoped could be begun early in 1928 at the new magnetic station Au Tau about 27 miles from the Hongkong Royal Observatory. Monthly absolute determinations at this new station from March to December, 1927, gave mean $D=0°\ 44'.4$W and $H=0.37433$ c. g. s. (0.37442 referred to the instrument used at Hongkong); inclination was not observed because the earth inductor was under repair.

[q] For nine months, from January to September; magnetic work discontinued at the end of September, 1923.

[r] Records at the Vieques Observatory were discontinued November 1, 1924 (values given for 1924 apply for the first ten months only), and a new observatory to replace it was built about eight miles south of San Juan, Porto Rico, where recording began January 1, 1926.

Observatory	Latitude	Longitude	Year	Declination (D)	Inclination (I)	Intensity Hor. (H)	Intensity Ver. (Z)
	° ′	° ′		° ′	° ′	c. g. s.	c. g. s.
Apia	13 48 S	171 46W	1925	10 22.8 E	30 07.9 S	.35239	.20453
			1926	10 26.1 E	30 08.3 S	.35216	.20446
Huancayo	12 03 S	75 20W	1924[e]	8 01.7 E	0 54.6 N	.29762	.00473
			1925[e]	7 59.1 E	1 01.5 N	.29750	.00532
			1926[e]	7 55.5 E	1 09.8 N	.29725	.00604
Tananarive	18 55 S	47 32 E	1913	8 31.4W	53 39.0 S	.22492	.30563
			1914	8 25.2W	53 37.9 S	.22484	.30532
Mauritius	20 06 S	57 33 E	1924	10 59.7W	52 32.2 S	.22943	.29940
			1925	11 09.6W	52 31.0 S	.22906	.29867
La Quiaca	22 08 S	65 43W	1920[e]	6 03.3 E	12 39.6 S	.26621	.05979
			1921[e]	5 57.3 E	12 37.9 S	.26557	.05949
			1922[e]	5 49.2 E	12 30.9 S	.26511	.05884
			1923[e]	5 40.2 E	12 29.5 S	.26505	.05881
			1924[e]	5 33.3 E	12 29.3 S	.26481	.05863
			1925[e]	5 29.1 E	12 28.2 S	.26435	.05848
Vassouras	22 24 S	43 39W	1924	11 53.9W	16 06.0 S	.24371	.07034
			1925	12 03.5W	16 15.6 S	.24333[s]	.07097
			1926	12 10.5W	16 31.2 S	.24293	.07205
Watheroo	30 19 S	115 53 E	1925[o]	4 17.6W	64 07.9 S	.24719	.50976
			1926[o]	4 17.2W	64 10.7 S	.24681	.51007
			1927[e]	4 16.3W	64 11.9 S	.24671	.51028
Pilar	31 40 S	63 53W	1922	7 31.9 E	25 39.1 S	.25178	.12091
			1923	7 23.1 E	25 38.4 S	.25139	.12066
Toolangi	37 32 S	145 28 E	1923	8 10.7 E	67 40.6 S	.22995	.56013
			1924	8 10.1 E	67 42.6 S	.22986	.56077
			1925	8 10.4 E	67 44.5 S	.22948	.56071
Christchurch	43 32 S	172 37 E	1925	17 21.1 E	68 14.2 S	.22166	.55522
			1926	17 26.0 E	68 15.6 S	.22141	.55525
Orcadas	60 43 S	44 47W	1911	4 48.8E[t]	54 26.5 S[u]	.25384[t]	......
			1912	4 46.5 E	54 26.0 S[e]	.25343	.35442[e]

[s] No values in June and only on four days in May and on seven days in July.

[t] Mean for nine months, from April to December.

[u] Mean of absolute values from March to December.

REVIEWS AND ABSTRACTS

(See also pages 90, 94, 104, 109)

PALAZZO, LUIGI: *Variazioni magnetiche secolari a Massaua col contributo di recenti misure.* Roma, Atti Pont. Accad. Sci. Nuovi Lincei, Anno 80, Sess. IV, 20 Marzo 1927 (165-174).

In this paper the author discusses some observations of the magnetic elements which he was able to make on his return trip to Rome from his visit to Italian Somaliland and Jubaland Province on the occasion of the total solar eclipse of January 14, 1926. During the brief stop of the steamer at the Port of Massaua, Eritrea, he found it possible to visit the station on the little island of Taulud where he himself had previously made magnetic observations in 1913, and which had been occupied by observers of the Carnegie Institution of Washington in 1911, 1914, and 1918. There are also available records of other observers obtained in 1839, 1840, 1849, and 1897, of which only the last are complete. More recently observations have been made by the officers of the *Ammiraglio Magnaghi*, engaged in hydrographic work in the Red Sea during 1923-1924. All these observations together with those made by the author on April 16 and 17, 1926, constitute a good series for the discussion of secular variation within a region where reliable sequences are much needed. The author discusses his results in connection with those of the previous occupations of the same station and finds that the west declination is at present decreasing at the rate of 4′.1 annually, at which rate the agonic line will reach the station in its western movement about the middle of the year 1930. This rate is somewhat less than he had predicted on the basis of the observations made prior to his last ones but whether this is but a temporary slowing down of the movement of the agonic line, only further observations will reveal. He also finds that the inclination is increasing at about 4′.8 annually which is somewhat greater than the rate indicated by the observations of 1897 and 1911. The concordance of the results of the observations of these two elements, the declination and the inclination, was sufficient to warrant the derivation of formulas by the method of least-squares, using for the purposes only the observations from 1911 to the present time, as follows

$$D = 1^\circ\ 20'.3 - 7'.22\ (t-1915) + 0'.132\ (t-1915)^2$$
$$I = 13^\circ\ 03'.0 + 5'.62\ (t-1915)\ - 0'.036\ (t-1915)^2$$

The paper is illustrated by graphs showing the trend of the secular changes in the value of each element, beginning with those of Rössler in 1897. The curves are drawn by passing a smooth line through the plotted points and are not those derived from the equations, since the observations of Rössler were considered too remote to be combined with the latest in deriving a formula. The points lie very close to the declination-curve and the deviations from the inclination-curve are on the order of the diurnal inequality.

Naturally the trend of the secular-change curve for horizontal intensity is more difficult to determine. In the northeastern part of Africa and the adjacent portions of Asia the annual changes in this element are very small, so that the diurnal range may exceed many times the mean change for a year, and similarly the mean value for an abnormal day may be higher or lower than the mean by an amount corresponding to the secular change of several years together. The author made his observations on the morning of April 17, just at the end of a period of considerable disturbance. It is not surprising therefore that his results show some disagreement from those at earlier dates. In his discussion of the secular change in horizontal intensity he finds evidence that the transition from a slow decreasing to a slow increasing rate has already taken place. H. W. FISK

FINAL RELATIVE SUNSPOT-NUMBERS FOR 1927

By W. Brunner[1]

The numbers in the table are based on observations made at the Zürich Observatory, supplemented by series furnished by 40 other observatories for the 68 days (indicated by asterisks) on which no observations were made at Zürich. The small increase of only 5.1 over the mean for 1926 (63.9) shows that we are nearing a sunspot maximum and, indeed, a rather low one.

Day	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	67*	122	41	77	48	32	98	49	61	43	65	35*
2	67*	136	46	81	53	42	120	59	61	32	56	26*
3	65	157	46	89	68	41	101	35	52	51	32	30*
4	81*	155	67	77	73	42*	111	50	37	65	25	17*
5	89	173	59	102*	99	51	97	51	50	82	45*	34*
6	76	119*	58	98	105	63	72	48	44	82	36	64*
7	111*	163	71	98	97	79	61	37	47	85	33*	58*
8	105	116	88*	80*	78	79	45	17	40	90	15	72
9	123*	127	91	136	91	57	54	18	44	95	46	88*
10	116*	124	46	101*	110	54	52*	19	47	115*	71	85*
11	124	106	55	163	101	63	42	32	68	112*	91*	85*
12	79*	82	50	137	143	72	16	31	92	74	101	53
13	53	58	74*	125	97	73	14	53	96	90*	113	62*
14	70	98	70	138	57	54	32	59	103	79	100	47*
15	68	71	105*	131	59	32	32	70	154	76*	91	20
16	76*	58	95	157	67	22	44	68	126	54*	84*	19*
17	88	79*	125	124	86	51	47	80	111	44	87	17
18	111	76*	126	120	98	37*	45	97	85*	32	81	10
19	89*	65	147	91	67	35	22	79	81	53	64	8
20	76*	67	114	66	72	26	34	58	81	40	79*	11*
21	70*	46	131	59	81	32	43	49	55	66	78	17
22	80	52	121	68	87	43	49	61	44	66*	70*	14*
23	65	53	82	62	88	45	49	68*	73	56	81	32
24	85*	45	56	49	101	64	52	68*	86*	65	88*	59
25	44	54	49	51	90	73	68	56	85*	69	87	63
26	42	59	23	90	86	88	68	56	58	46	70	33
27	38	79	38*	93*	88	80	75	58	77	25	67	56
28	49	64	16	40	43	116	34	52	38	25	45*	64*
29	64	...	31	55	58	114	44*	68	27	29	59*	70*
30	109	...	16	48	34	113	39	66	30*	40	57*	73*
31	149	...	21	...	28	...	43	56	...	75	...	79*
Mean	81.6	93.0	69.6	93.5	79.1	59.1	54.9	53.8	68.4	63.1	67.2	45.2

Mean number for the year 1927: 69.0

[1]Abstracted from Astronomische Mitteilungen, Zürich, N. 117, 1928 (225-239).

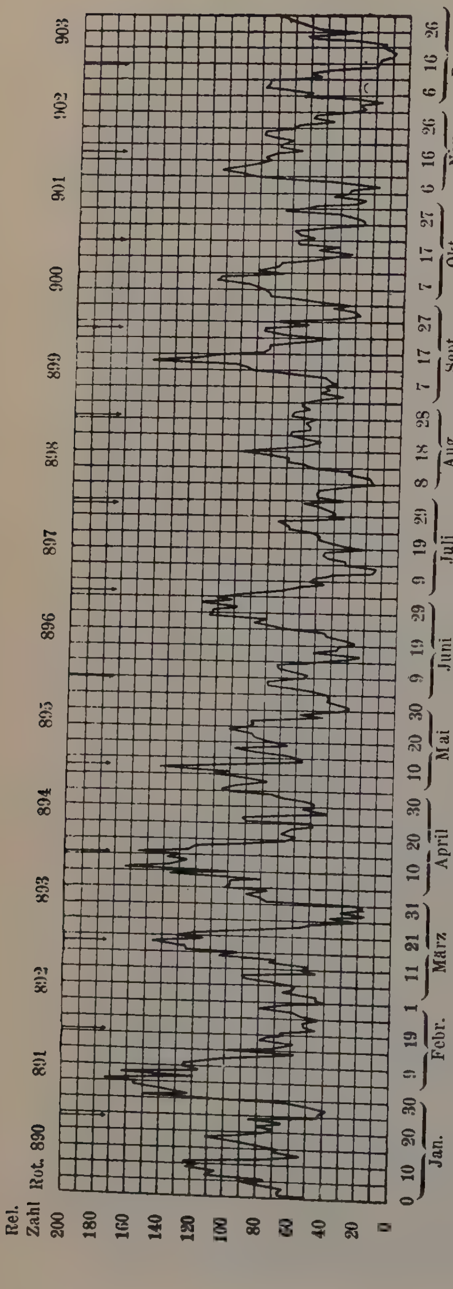


FIG. 1—Final relative sunspot-numbers for the year 1927

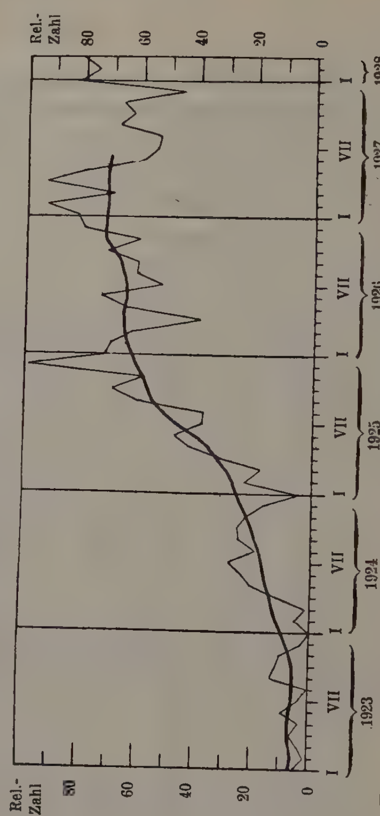


FIG. 2—Observed and smoothed monthly final relative sunspot-numbers for the period 1923-1928

Figure 1 is a detailed graphical representation of the daily relative sunspot-numbers for 1927 in which the times are plotted as abscissas, and the relative numbers, taken from the table, as ordinates. The limits of the successive solar rotations are indicated by vertical arrows in the upper edge of the figure. The secondary

maxima and minima succeeding the rotation periods do not represent real fluctuations in sunspot-activity but are rather to be attributed to the influence of solar rotation, and moreover, to a certain stability of centers of activity for spots and the special distribution of these centers in the direction of rotation.

Figure 2 shows the observed and smoothed monthly relative numbers for the the period 1923 (year of sunspot minimum) to 1928. The purpose of smoothing is to eliminate the secondary variations and to exhibit more clearly the real course of the curve. The method of smoothing is as follows: For obtaining the mean for the epoch July 1, the mean of the monthly means of the twelve months, January to December, is taken (m_1), and for that of August 1, the mean of the monthly means for February to January (m_2). The mean of these is then taken $m=(m_1+m_2)/2$ which represents the smoothed relative number for the middle of July, the value utilized for the construction of the curve.

Zürich, Switzerland.

WOLFER PROVISIONAL SUNSPOT-NUMBERS FOR APRIL AND MAY, 1928

(Dependent alone on observations at Zürich Observatory)

BY A. WOLFER

Day	Apr	May	Day	Apr	May
1	..	124	16	82	16
2	..	126	17	..	15
3	76	126	18	26	13
4	95	109	19	39	15
5	111	114	20	40	0?
6	126	117	21	22	14
7	121	142	22	21	22
8	136	133	23	24	41
9	134	146	24	28	34
10	109	119	25	44	49
11	125	85	26	52	40
12	110	62	27	50	54
13	93	34	28	55	112
14	82	26	29	67	131
15	91	15	30	92	150
			31	..	153

Mean for April (27 days): 76.0
Mean for May (31 days): 75.4

REVIEWS AND ABSTRACTS

(See also pages 90, 94, 100, 109)

PEDERSEN, P. O.: *The propagation of radio waves along the surface of the Earth and in the atmosphere.* Copenhagen, Danmarks Naturvidenskabelige Samfund, A. Nr. 15a, 1927, 244 pp., with appendix (A. Nr. 15b) 19 pp. 25 cm.

This book is not only a technical review of the theoretical and experimental status of the subject but also a presentation of many original and important developments by the author. At the same time it is a handbook to the extent of giving complete formulas for calculations of conductivities, refractive indices, attenuation-constants, etc., as well as nomograms in the appendix. The propagation of electromagnetic waves over the surface of a sphere is taken up first by approximate methods. It is shown that diffraction alone is insufficient to account for observed signal-strengths. The part played by the upper atmosphere is thus made clear. The composition and pressure of the atmosphere at great heights is next discussed. The conclusion is reached that information obtained from radio is, after all, the most reliable. Questions of ionization and ionic recombination are then taken up with particular attention to low pressures. The errors in older conclusions regarding the insufficiency of ultraviolet solar radiation as an ionizing agent are considered. A very interesting point about stellar radiation having an ionizing power about one thousandth of that of the Sun is mentioned. Formulas for the conductivity are worked out more completely than elsewhere, taking account of collisions, of the Earth's magnetic field, of various directions of propagation, as well as of the frequency. The attenuation of the waves in the upper atmosphere is discussed. The radical modifications necessary in the Schuster-Chapman theory of variations in the Earth's magnetic field are brought out.

In some minor points we do not entirely agree with the author. Thus, on page 110 a result for the rotation of the plane of polarization is obtained which is twice that arrived at by Nichols and Schelleng. It seems that the author defines the rotation of the plane of polarization for a vibration of variable phase (see his formulas (51), (52), page 109) rather than constant as is customary in optics. This accounts for the difference between his result and that of Nichols and Schelleng. The absence of a polarization force $(4\pi/3)/P_0$ in a gas does not seem obvious to us. However, these points are decidedly minor. The book is a very thorough piece of work and will undoubtedly help many workers in the field. G. BREIT

HEINE, W.: *Elecktrische Bodenforschung, ihre physikalischen Grundlagen und ihre praktische Anwendung.* Berlin, Gebrüder Borntraeger, 1928 (xi+222 mit 117 Figuren im Text). 25 cm. (Sammlung geophysikalischer Schriften, Nr. 8.)

By confining this treatise to electrical methods the author has succeeded in treating more extensively the theory bearing on such methods and the interpretation of the results they yield, than has been done heretofore in one publication.

The three subdivisions of the treatise are: (I) Survey of the electric field (pp. 3-117); (II) The magnetic field of alternating currents in the Earth (pp. 117-180); (III) The application of electromagnetic waves in the search for conducting deposits (pp. 180-201). A list of 59 German patents for methods of electrical prospecting is appended.

The theoretical treatment can be readily followed by one familiar with the fundamentals of electricity; the deductions are amply illustrated by diagrams; the descriptions of methods are necessarily rather brief and general.

O. H. GISH

LETTERS TO EDITOR

ON THE REVISION AND CORRECTION OF FOURIER-ANALYSIS COMPUTATIONS

I have read with interest the article in volume 32 of the JOURNAL, page 155, by C. C. Ennis, "On the revision and correction of Fourier-analysis computations." The formulæ on page 156 are those I have been in the habit of using, but I have found it an economy of time to begin by grouping the terms in pairs, viz, sums t_1+t_{23}, t_2+t_{22}, etc., all occurring in the calculation of the a-coefficients, and differences t_1-t_{23}, t_2-t_{22}, etc., occurring in the calculation of the b-coefficients.

The late Professor S. P. Thompson, who interested himself many years ago in the subject, especially in its application to electrical engineering, where high harmonics are sometimes dominant, carried the grouping process much further. A point worthy of notice is that the four-figure values of sin 75°, sin 60°, sin 45°, and sin 15°, viz, 0.9659, 0.8660, 0.7071, and 0.2588, agree so closely with the three-figure values that the employment of the latter, which admits the use of Crelle's tables, gives higher accuracy than we should expect *a priori*.

My personal predilection is to apply a non-cyclic correction *before* calculating Fourier coefficients, but the data at the foot of page 162 at least emphasize the uncertainties in Fourier coefficients when the non-cyclic change is large, as is apt to be the case in the diurnal variation of atmospheric-electric potential-gradient if based on only a few days' observations.

C. CHREE

75 Church Road,
Richmond, Surrey, England,
April 28, 1928

REMARQUES À PROPOS DES MESURES MAGNÉTIQUES DE M. PARKINSON ET DES FORMULES DES VARIATIONS SÉCULAIRES À TUNIS

En examinant le Vol. VI des Researches of the Department of Terrestrial Magnetism, "Land Magnetic and Electric Observations, 1918-1926," j'ai vu, entre autres choses, que des mesures magnétiques ont été faites par l'observateur M. Parkinson dans la "Repeat" station de Tunis en février 1922. Moi aussi, j'ai fait itérativement des déterminations magnétiques à Tunis, et la dernière fois fut en octobre 1923; après cela j'ai entrepris l'étude des variations séculaires à Tunis, en publiant une note intitulée: "Variazioni magnetiche secolari a Tunisi, Cartagine e Malta" (Mem della Pontif. Accademia delle Scienze Nuovi Lincei, Vol. VIII, 1924-1925). J'avais aussi calculé, sur la base de toutes les obser-

vations dont je possédais alors les valeurs (Denza 1877.8, Teisserenc de Bort 1883, Moureaux 1887.4, Palazzo 1896.6, Sligh 1911.9, Palazzo 1923.9) et par l'application de la méthode des moindres carrés, les formules suivantes représentant la marche séculaire de D et H:

$$D = 10° \, 21'.9 - 6'.06t - 0'.055t^2$$
$$H = (25691 + 15.7t - 0.506t^2)\gamma$$

où t est l'an compté à partir de 1900.

Je regrette que dans ces calculs je n'aie pas utilisé aussi les observations de M. Parkinson, pour la raison que j'ignorais alors, comme j'ai ignoré jusqu'aujourd'hui, que M. Parkinson eût fait des observations à Tunis en 1922.

Maintenant j'ai eu la curiosité de vérifier tout de suite si mes formules empiriques étaient satisfaites aussi par les valeurs trouvées par M. Parkinson. Voici l'accord surprenant que j'ai trouvé

	D	H
Calculé au moyen des formules pour l'époque 1922.1	7°48'.1	25791γ
Observé par Parkinson en 1922.1 (résultat moyen)	7 47 .6	25796
Différences $(C-O)$	+0 00 .5	−5

Les différences entre les résultats des formules et les observations Parkinson sont donc pratiquement nulles. Pour l'inclinaison je n'avais calculé aucune formule, dans le genre des précédentes pour D et H, et cela pour la raison que la courbe dessinée par moi pour la marche séculaire de I ne se prêtait pas à être représentée par une équation parabolique. J'observe toutefois que de la courbe empirique dessinée par moi sur les observations faites et reproduite dans les tableaux graphiques annexes au Mémoire sus-cité, on tire pour l'époque 1922.1 l'ordonnée correspondante $I = 52° \, 03'.0$. Les observations de Parkinson donnent $I = 51° \, 54'.6$, qui diffère de la valeur précédente seulement par $-8'.4$.

En ce qui concerne la correspondance presque absolue entre calcul et observation pour D et H, je n'entends pas en exagérer l'importance, car on peut penser qu' à un tel accord aient contribué d'heureuses combinaisons entrées en jeu; mais cependant il est très satisfaisant pour moi de constater la parfaite adaptabilité de mes formules à représenter aussi les observations de Parkinson. La conclusion que j'en tire, est que: quand même j'eusse connu les observations de Parkinson alors que j'entreprenais les calculs pour représenter la marche séculaire des éléments D et H à Tunis, je serais parvenu à des formules non sensiblement différentes de celles que j'ai rapportées ci-dessus.

LUIGI PALAZZO

R. Ufficio Centrale di Meteorologia e Geodinamica,
Rome, le 4 mai 1928

PRINCIPAL MAGNETIC STORMS RECORDED AT THE SITKA MAGNETIC OBSERVATORY, JANUARY TO MARCH, 1928[1]

(*Latitude 57° 03′.0 N.; longitude 135° 20′.1* or *9*^{h} *01*^{m}*.3 W. of Gr.*)

Greenwich Mean Time			Range		
Beginning		Ending	Decl'n	Hor. int.	Vert. int.
1928	*h m*	*d h m*	′	γ	γ
Jan. 27	2 16	27 22 ..	76.8	685	660*
Mar. 11	9 37	12 7 ..	145.0	877*	452*

*Curve went off paper in one direction.

January 27, 1928—This is a small storm with abrupt beginnings recorded on all three of the components. Beginning at 10^h 30^m *H* and *Z* drop considerably and come back to normal about an hour later, making the curves appear like a sharp wedge at this time. The active part begins at 9^h and lasts about four hours.

March 11, 1928—The beginning of this storm is gradual, the *Z* seeming to just wander up and off the paper till the storm is over. The *D* and *H* are moderately active until the thirteenth hour, *D* increasing and *H* decreasing to that time. From 13^h to 16^h these elements are very active, the spots being faint lines only because of the rapidity of the motion, and both record very low values. At 16^h the storm begins to decrease with fluctuations and is soon back to normal.

F. P. Ulrich, *Observer-in-Charge*

[1]Communicated by E. Lester Jones, Director, United States Coast and Geodetic Survey.

PRINCIPAL MAGNETIC STORMS RECORDED AT THE HUANCAYO MAGNETIC OBSERVATORY, JANUARY 1 TO APRIL 30, 1928

(*Latitude* 12° 02′.7 *S.; longitude* 75° 20′.4 or 5^h 01^m.4 *W. of Gr.*)

March 11, 1928.—A short magnetic storm on March 11, beginning at 6^h and ending about 17^h, was characterized by severe fluctuations in the horizontal intensity, but the declination and vertical intensity were also affected. It began by a slow fall in the horizontal intensity over about two hours, followed by more rapid and intensive fluctuations which were at their maximum between 8^h and 15^h. Beginning at 8^h 29^m a sharp drop of 140 gammas in less than five minutes took place, followed by a moderate peak and another deep bay, all badly broken up and irregular. After another high peak subsequent to 12^h, a very sharp drop again began at 12^h 58^m (202 gammas in six minutes). The declination also showed this second drop, but the time of commencement was four minutes later at 13^h 02^m. The storm died down rapidly after 15^h, and after 17^h was evident only by a low and somwhat ir-

regular horizontal-intensity for several hours. The ranges were: Declination, 7′.8; horizontal intensity, 443 gammas; vertical intensity, 33 gammas. *All times given are Greenwich civil mean time.*

There were no marked disturbances during January, February, or April.

PAUL G. LEDIG, *Observer-in-Charge*

PRINCIPAL MAGNETIC STORMS AND EARTHQUAKES RECORDED AT THE WATHEROO MAGNETIC OBSERVATORY, JANUARY TO MARCH 1928

(*Latitude 30° 19′.1 S.; longitude 115° 52′.6 or 7ʰ 44ᵐ E. of Gr.*)

There were no marked magnetic disturbances during the first quarter of 1928.

No disturbances were recorded on the magnetograms of the type usually attributed to earthquakes during January and February, 1928. On March 16 an earthquake of moderate intensity began at $5^h\,27^m$ for horizontal and vertical intensity and ended at $5^h\,33^m$ and $5^h\,35^m$ for horizontal and vertical intensity, respectively, the maximum amplitude in horizontal intensity being 2.2 mm and that in vertical intensity being 0.8 mm. It was barely distinguishable on the declination trace, while *P* and *S* waves appeared on both horizontal and vertical-intensity traces. *All times given are Greenwich mean civil time.*

H. F. JOHNSTON, *Observer-in-Charge*

PRINCIPAL MAGNETIC STORMS RECORDED AT THE CHELTENHAM MAGNETIC OBSERVATORY, JANUARY TO MAY, 1928[1]

(*Latitude 38° 44′.0 N.; longitude 76° 50′.5 or $5^h\,07^m.4$ W. of Gr.*)

March 11, 1928—There was a moderate disturbance beginning March 11 at 10^h which ended at 4^h on March 12.

May, 27, 1928—This storm, which began at 15^h and ended at about 10^h May 29, was not of the first magnitude. It developed gradually from the beginning, the principal portion extending from 2^h May 28 to 2^h May 29, with principal phases as follows:

Element	Time of maximum	Time of minimum
D	May 29, $3^h\,31^m$, also May 29, $3^h\,56^m$	May 29, $2^h\,45^m$
H	May 28, $15^h\,31^m$	May 28, $20^h\,36^m$
Z	May 28, $19^h\,00^m$	May 29, $3^h\,50^m$

The ranges were 43′.4, 337 gammas, and 380 gammas in declination, horizontal intensity, and vertical intensity, respectively.

All times given are Greenwich mean civil time.

G. HARTNELL, *Observer-in-Charge*

[1]Communicated by E. Lester Jones, Director, United States Coast and Geodetic Survey.

REVIEWS AND ABSTRACTS

(See also pages 90, 94, 100, 104)

J. Koenigsberger: *Zur Deutung der Karten magnetischer Isanomalen und Profile.* Beitr. Geophysik, Leipzig, Bd. 19, Heft 2/3, 1928 (241–291). [Author's summary preceding article.]

The isanomal curves for vertical and horizontal intensity and for declination on the Earth's surface are given by formulæ and figures for a sphere and for an oblate spheroid (ellipsoid of revolution) under the induction of the earth's magnetic field. The depth of their center under the Earth's surface can be obtained if certain isanomal curves or some points of these are known. The formulæ for the anomaly of the vertical component are given for elongated ellipsoid of revolution with vertical axis and for an oblate spheroid in different positions; their characteristic parameters can be found in tables which enable us to find, by interpolation, the center depth and, in case of comparatively small depth, the form and position of the ellipsoid.

In the tables a is the shorter and $b=c$ the longer axis of the oblate rotational ellipsoid; h the depth of the center of the ellipsoid under the surface of the Earth, d_m is the distance between the central (positive) extreme (Z_m) and the isanomal of the one half of this maximum value $= Z_m/2$; d_h is the distance between the one-half and the one-fourth of this maximum value and d_t between one-fourth and one-tenth. g_1 is d_m/d_h; g_2 is d_h/d_t.

The following conclusions can be drawn from the exact theory (for inclinations between 60° and 75°), and partially coincide with the theses of earlier authors:

(1) The anomalies are weaker and the diameter of the curves greater the greater the distance of the disturbing mass from the Earth's surface (Hotchkiss).

(2) The depth of the center of the magnetic disturbing mass is approximately threefold the mean distance for the magnetic N, S, W, E directions of isanomal curves for the value of the fourth and the tenth part of the central extreme value. The exact determination of depth is possible according to the data in the tables, also in case of the mass not being a spheroid; provided that the magnetic susceptibility is less than or equal to 0.1, an irregular mass can be considered as an aggregate of ellipsoids.

(3) The outer (negative) northern extreme is as large or larger than the central extreme if the oblate ellipsoid dips under 10° to 20° to the (magnetic) south (Broderick). If it dips under such an angle to the north, the largest outer (negative) extreme lies south of and is weaker than the central extreme.

(4) If one diameter of the horizontal projection of the mass is much larger than the others (e.g. of an elongated ellipsoid or of an infinite elliptic cylinder), the isanomal curves are much larger in this direction than in the others (magnetic lines of strength, Hotchkiss, Aldrich). An oblate ellipsoid also gives a "magnetic line" if dipping under a larger angle.

(5) The dipping of an oblate ellipsoid or elliptic cylinder makes the isanomales come nearer together on the higher side than on the lower dipping side. The one-tenth isanomal curve for relatively low depth of the mass, b, a greater than or

equal to $0.4h$ gives the contour-line of the upper surface of the disturbing mass; the curves are then generally not circles and g_1 and g_2 different from the value of the sphere.

(6) An oblate spheroid with b greater than a has no magnetic effect. Therefore intrusive masses of a temperature higher than the critical temperature of magnetite or masses of molten magma in a solid basic magma of low temperature and, therefore, higher susceptibility have the effects of magnetic holes with high negative susceptibility and can therefore give a high negative central extreme.

(7) Inflexions in the curvature of isanomales allow us to estimate the depth of the upper surface of the disturbing mass. The distance between the point or points of inflexion which terminate the change of curvature on a piece of the curves is approximately $= 2.2h$.

(8) If the center of the disturbing mass lies deep compared with its dimensions, $(b^2-a^2)/h^2$ less than or equal to 0.2, the isanomal curves are circles and the parameters are similar to those of the sphere.

Conclusions drawn from magnetic charts of vertical-intensity anomalies: The magnetic anomalies give depths of the center of the disturbing mass from the surface between 0.2 to 20 km; often 3 to 8 km would be found. The conducting channels or masses belonging to effusive rocks on the surface have a depth of 3 to 6 km; their continuation down to the plastic zone is dipping under gentle angles (of 20° to 50°?).

The higher zone, partially of effusive type, of these basic rocks has a depth of center from 300 to 1000 meters, and the same is approximately true for some so-called plutonic or hypoabyssal rocks, which therefore do not always continue in great depths. The great anomalies marked on maps with scale of 1:1000000 or more have very varying depth of center from 0.3 to 20 km.

NOTES

13. *Investigations of Terrestrial Magnetism in Greenland*—The following is a translation of some notes on a paper by Dr. D. la Cour, Director of the Danish Meteorological Institute, entitled "Les recherches récentes au Groenland sur le magnétisme terrestre." The paper was read before the Royal Danish Academy of Science and Letters and the notes were kindly furnished by Dr. Martin Knudsen, Secretary of that Academy. "For the study of the variations of the magnetic field of our Globe and of certain relations between the Sun and the Earth, the study of magnetic variations in the vicinity of the Earth's magnetic poles offers particular interest. However, the number of long series of such observations is not large and, at the instance of the International Geodetic and Geophysical Union, Denmark has contributed toward remedying this defect by constructing a permanent magnetic observatory at Godhavn. This observatory is situated in a higher north magnetic latitude than any other observatory and, particularly through direct determinations of the vertical intensity as well as by use of special recording devices, it is in a position to obtain a greater accuracy in many domains of investigation than has been attained up to the present time in the arctic regions. The observatory has been in operation for two years and besides the characteristic daily course of the magnetic elements, its registrations give evidence,

among other things, of further relations between magnetism and the rotation of the Earth as well as between magnetism and the rotation of the Sun."

14. *Magnetic Station at Au Tau*—It is stated in the Report of the Director of the Royal Observatory, Hongkong, that the buildings for the new magnetic station at Au Tau were completed in March, 1927. The coordinates of the pier used for absolute measures of magnetic declination and horizontal force are: Latitude 22° 26′ 50″.6 north, longitude 114° 02′ 40″.5 east. Monthly determinations of horizontal force and declination were made simultaneously with those at the Royal Observatory, Hongkong, from March to December, 1927, the new magnetometer (Cooke Troughton and Simms No. 31) being used for the purpose. The results (mean for 10 months) are: Declination (west) 0° 44′.4; horizontal force 0.37433 C. G. S. unit.

15. *Magnetic Results in the U. S. S. R.*—Professor Boris Weinberg of Leningrad has kindly sent us 128 advance pages of the "Catalogue of Magnetic Determinations made from 1556 to 1925 (inclusive) in the U. S. S. R." which he is compiling. In this publication he has tried to collect all the results of magnetic observations made in the vast territory of the Union of Socialistic Soviet Republics embracing about one-fourth of the land surface of the Globe. The values are arranged in tables of 12 columns containing: (1) Name of station; (2) λ=longitude; (3) ϕ= latitude; (4) t=year of observation; (5 to 10) D_t, D_{25}, I_t, I_{25}, H_t, H_{25} which denote the observed values and the values reduced to the epoch 1925.5 of the declination (D), inclination (I), and horizontal intensity (H), respectively; (11) p=relative weights from 1 to 10 adopted conventionally by the author for estimating the comparative value of the determinations; (12) observer or organization responsible for the observation. The stations are arranged in zones of two degrees of latitude according to increasing longitudes (east from Greenwich). The names of the stations and observers are given in Russian but a key is provided to assist in the transliteration and pronunciation of the names. The tables are preceded by an "Explanation" in Russian and English containing all pertinent information regarding them.

This important compilation of magnetic results will not only perform the useful service of making available in compact and convenient form a vast amount of observational data which heretofore could only be obtained from sources not easily accessible to students of geophysics but also, by indicating clearly the present status of the distribution of magnetic stations in the U. S. S. R., will furnish a definite basis on which the systematic magnetic-survey of the Soviet Republics may be planned.

16. *Geophysical Museum, Leningrad*—On November 28, 1927, there was inaugurated at the Central Geophysical Observatory, Leningrad, a Geophysical Museum, in which it is proposed to show, by means of exhibits, the progress and achievements in all the branches of practical and scientific geophysics. To this end, the Central Geophysical Observatory is soliciting, from the various institutions and organizations engaged in the study of geophysics, contributions of material for exhibits such as, for example, bibliographies and copies of articles and publications, diagrams, maps, photographs of equipment and of instruments and eminent workers, models illustrating the work done and instruments employed, in short, anything that may be found appropriate for the purposes of the Museum.

17 *New Geophysical Laboratory on the Pic du Midi*—We are pleased to learn from *L'Astronomie* of the proposed erection of a laboratory for geophysics in con-

nection with the Observatoire du Pic du Midi (2860 meters), regarding which the director, C. Dauzère makes the following statement: "La construction d'un laboratoire de Physique du Globe a été entreprise en 1927. L'emplacement est déjà nivelé, les fouilles sont faites, les pierres et le sable ont été extraits du sol et préparés. La maçonnerie sera exécutée en 1928; le travail sera repris dès que la fonte des neiges rendra l'Observatoire accessible. Les nouveaux locaux permettront quelques installations particulières, parmi lesquelles celles qui sont relatives à électricité atmosphérique et à l'actinométrie nous paraissent les plus urgentes, mais quelques années seront encore nécessaires pour réaliser les améliorations essentielles, qui feront de l'Etablissement un véritable Institut de Physique du Globe, comme se lit son titre actuel." We have no doubt that under the improved conditions of work, further valuable researches in terrestrial electricity will be carried out, especially when we recall that the important contributions to the subject by Marchand and Lejay emanated from this Observatory.

18. *Northern Light Observatory, Tromsö*—According to a circular letter received from the Norwegian Meteorological Institute, publications which have heretofore sent to the Geofysisk Institutt, Tromsö, Norway, should henceforth be addressed to Nordlysobservatoriet, Tromsö, Norway.

19. *Aeroarctic*—The society Aeroarctic will hold its second general assembly in Leningrad from June 18 to 23, 1928. Among the papers of especial interest to readers of the Journal, are the following: Prof. Störmer, Probleme und Richtlinien der künftigen Erforschung des Polarlichtes; Profs. Achmatow and Rose, Kartographie der Arktis, erdmagnetische Untersuchungen.

20. *Exhibition of Geophysical Instruments*—Geophysical prospecting will be the principal feature at the meeting of the American Institute of Mining and Metallurgical Engineers to be held in Boston, Massachusetts, August 29–31, 1928. An exhibition of instruments used in geophysical prospecting will be held at the Massachusetts Institute of Technology, Cambridge, Mass. Demonstrations of instruments will be permitted on the Technology grounds. On Wednesday afternoon, August 31, a special excursion to the Massachusetts Institute of Technology will afford an opportunity for those attending the meeting to visit the exhibit. The exhibition rooms at Technology, however, will be accessible to exhibitors and visitors from 8:30 a. m. to 5:00 p. m. on all three days of the meeting.

The Exhibition Committee are desirous of having a thoroughly representative exhibit. There is available an abundance of very desirable space and prospective exhibitors are assured that their requirements will be met if they will inform the Committee promptly regarding the amount of space desired. Rooms may be occupied a day or two in advance for preparing the exhibits. Instruments and other material should be shipped, with transportation charges prepaid, "Care of W. Spencer Hutchinson, Chairman A. I. M. E. Exhibition Committee, Room 8–219, Massachusetts Institute of Technology, Cambridge, Massachusetts." There will be no charge for space. Further information can be secured by addressin the Chairman of the Committee.

21. *Personalia—Prof. E. Wiechert*, Director of the Geophysical Institute and Professor at the University of Göttingen, died on March 19, 1928, aged 67 years. *Prof. Otto Nordenskjöld*, well-known Swedish arctic and antarctic explorer and professor at the University of Gothenberg, died on June 2 at the age of 58 years.

Antoni B. Dobrowolski, formerly Vice-Director of the Meteorological Institute of Poland, and *Stefan Hlasek*, formerly Director of the Meteorological and Magnetical Observatory at Pavlovsk and of the Geophysical Observatory at Tiflis, have been appointed Director and Vice-Director, respectively, of the Meteorological Institute of Poland. *Dr. Gorczynski*, we are informed, has retired from the directorship.

Dr. F. Lindholm has been appointed Director of the Physical Meteorological Observatory at Davos, to succeed *Prof. C. Dorno* who retired from all active association with the Observatory on April 1, 1928.

Commander N. H. Heck, chief of the division of terrestrial magnetism and seismology of the U. S. Coast and Geodetic Survey, returned from Alaska to Washington on June 8. During his inspection trip the observatories at Tucson and Sitka were visited and plans for various improvements studied. At Tucson attention was given the possibility of taking up atmospheric-electric work; a station there would be of peculiar value because of cooperative work with the University of Arizona in solar radiation and in radiometer-operation at the Desert Sanitarium recording ultra-violet radiation. At Sitka chief attention was directed towards plans for development of a first-class seismological station. At Fairbanks, Alaska, it was found practical to establish a cooperative seismological station at the Alaska Agricultural College and School of Mines; this will be one of the farthest north seismological stations in existence.

R. R. Bodle has been engaged in field magnetic work for the Coast and Geodetic Survey in the western states since April 7; he will soon be relieved by *Professor S. A. Deel*, who will continue the work during the summer.

F. P. Ulrich of the Sitka Magnetic Observatory left early in June for the interior of Alaska to make field magnetic observations and especially to reoccupy repeat-stations. He is using a power-launch and expects to ascend several of the rivers to the north of the Yukon so as to establish some repeat-stations farther north than any now existing. During his absence the routine work of the observatory will be done temporarily by *R. H. Paddock* of the Sheldon-Jackson School at Sitka under the administrative direction of *Lieutenant H. A. Cotton*, who is commanding the steamer *Explorer* based at Sitka during the present field season.

R. Glenn Madill, of the Dominion Observatory, Ottawa, and an assistant, will leave about the middle of June to make measurements of magnetic intensity, declination, and dip at Port Burwell, Resolution Island, Cape Hopes Advance, Charles Island, Wakeham Bay, Nottingham Island, and other points along Hudson Strait. The data, to be secured primarily for the purpose of extending the study of the secular variation, will have an immediate practical application in navigation. Aurorae and magnetic disturbances will be studied as well.

J. A. Fleming has been reelected General Secretary of the American Geophysical Union for a period of three years beginning July 1, 1928.

Dr. Albert Wigand, professor of physics, geodesy, meteorology, and climatology at the Landwirtschaftliche Hochschule, Hohenheim, and docent of meteorology at the Technische Hochschule, Stuttgart, has been appointed professor of meterology at the University of Hamburg.

Dr. J. H. Jeans, secretary of the Royal Society, is one of the knights of this year's King's Birthday honours list.

LIST OF RECENT PUBLICATIONS

By H. D. Harradon

A—Terrestrial and Cosmical Magnetism

Antipolo Observatory. Hourly results of the observations made at the Magnetic Observatory of Antipolo near Manila, P. I., during the calendar year 1924. (Part IV of the annual report of the Weather Bureau for the year 1924.) Manila, Bureau of Printing, 1927, 47 pp. 29 cm.

Dyson, F. W. Report of the Astronomer Royal to the Board of Visitors of the Royal Observatory, Greenwich. Read at the Annual Visitation of the Royal Observatory, 1928, June 2. Greenwich, Royal Observatory, May 21, 1928, 18 pp. 31 cm. [The report refers to the period May 11, 1927 to May 10, 1928, and contains an account of the magnetic work at Abinger Observatory during that time.]

Eblé, L., et J. Itié. Valeurs des éléments magnétiques à la station du Val-Joyeux (Seine-et-Oise) au ler janvier 1928. Paris, C.-R. Acad. sci., T. 186, No. 12, 1928 (778).

Eve, A. S., and D. A. Keys. Geophysical prospecting. Scientific methods by which trained geologist-technicians are aided in the search of hidden minerals. Sci. Amer., New York, N. Y., v. 138, May, 1928 (414-417); June, 1928 (508-511, 561).

Gallo, J. El Observatorio Astronómico Nacional en su quincuagésimo aniversario. Tacubaya, D. F. (Mexico), 1928 (28 con láminas). 19 cm. [Brief history of the National Observatory of Mexico during the fifty years of its existence. Pp. 13-15 are devoted to the work in terrestrial magnetism.]

Gernet, A. von. Ueberblick über den Gang des magnetischen Vermessung der Ostsee. Zs. Geophysik, Braunschweig, Jahrg. 4, Heft 1, 1928 (27-33).

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The Carnegie setting sail May 10, 1928, from Chesapeake Bay for the first passage of Cruise VII

Terrestrial Magnetism
and
Atmospheric Electricity

VOLUME 33 SEPTEMBER, 1928 No. 3

PRELIMINARY RESULTS OF OCEAN MAGNETIC OBSERVATIONS ON THE *CARNEGIE* FROM WASHINGTON TO PLYMOUTH, HAMBURG, AND REYKJAVIK, MAY TO JULY, 1928

BY J. P. AULT, *Commanding the Carnegie*

TABLE 1—*Preliminary magnetic results, Cruise VII of Carnegie, Atlantic Ocean, May to June, 1928*
[*Observers:* J. P. Ault, O. W. Torreson, F. M. Soule, W. E. Scott, and J. H. Paul]

Date	Latitude	Longitude east	*Carnegie*-values			Chart-differences[a]								
						Declination			Inclination			Hor. intensity[b]		
			D	*I*	*H*	Br.	Ger.	U. S.	Br.	Ger.	U. S.	Br.	Ger.	U. S.
1928	° ′	° ′	°	°	*c.g.s.*	°	°	°	°	°	°			
May 11	37 06 N	285 14	7.2W	...	...	−0.1	+1.0	0.0	...	...	...	...	...	...
11	37 21 N	286 52	...	...	.194	...	...	...	...	...	...	0	−2	−2
11	37 22 N	287 15	...	69.9 N	...	...	...	...	+0.1	+0.2	+0.2	...	...	...
11	37 23 N	287 27	9.6W	...	...	−0.5	−0.1	−0.3	...	...	...	...	...	...
12	37 56 N	290 24	12.1W	...	...	−0.1	−0.1	0.0	...	...	...	...	...	...
12	38 05 N	292 52	14.5W	...	...	−0.5	−0.2	−0.4	...	...	...	...	...	...
13	37 55 N	295 24	15.8W	...	...	−0.1	−0.1	0.0	...	...	...	...	...	...
13	37 38 N	297 03	...	69.2 N	.193	...	...	...	+0.2	−0.1	+0.2	0	0	−3
13	37 32 N	297 32	17.5W	...	...	−0.6	−0.8	−0.7	...	...	...	...	...	...
15	37 08 N	303 46	...	...	.201	...	...	...	...	...	...	+1	+2	+1
15	37 16 N	304 20	20.7W	...	...	−0.5	−0.2	−0.7	...	...	...	...	...	...
16	37 39 N	306 07	21.9W	...	...	−0.8	−0.9	−1.0	...	...	...	...	...	...
16	37 56 N	307 39	22.6W	...	...	−0.8	−0.5	−1.0	...	...	...	...	...	...
17	38 07 N	309 33	22.6W	...	...	0.0	+0.2	0.0	...	...	...	...	...	...
17	38 10 N	310 51	...	...	.202	...	...	...	...	...	...	0	+2	0
17	38 08 N	311 20	...	66.3 N	...	...	...	...	−0.1	−0.7	−0.1	...	...	...
17	38 07 N	311 22	23.6W	...	...	−0.8	−0.2	−0.7	...	...	...	...	...	...
19	40 14 N	317 20	24.9W	...	...	0.0	+0.3	−0.2	...	...	...	...	...	...
19	40 46 N	318 36	...	66.2 N	.199	...	...	...	+0.1	−0.4	+0.1	+1	+1	−2
20	41 35 N	320 35	24.9W	...	...	+0.7	+1.1	+0.3	...	...	...	...	...	...
20	42 43 N	322 08	25.8W	...	...	+0.4	+0.5	−0.3	...	...	...	...	...	...
21	43 48 N	323 26	25.1W	...	...	+1.4	+1.7	+0.7	...	...	...	...	...	...
21	44 05 N	324 10	...	66.9 N	.193	...	...	...	−0.3	−0.4	+0.1	+1	+2	−1
21	44 12 N	324 30	25.2W	...	...	+1.1	+1.5	+0.6	...	...	...	...	...	...
22	44 53 N	325 47	25.7W	...	...	+0.6	+0.8	0.0	...	...	...	...	...	...
22	45 46 N	327 10	25.4W	...	...	+0.8	+0.9	+0.4	...	...	...	...	...	...
25	43 19 N	329 18	23.4W	...	...	+0.9	+1.0	+0.5	...	...	...	...	...	...
26	43 46 N	330 55	23.8W	...	...	+0.2	0.0	−0.2	...	...	...	...	...	...

[a]Charts used for comparisons: U. S. Hydrographic Office charts 1700, 1701, and 2406 for 1925; British Admiralty charts ...75 for 1927, 3598 and 3603 for 1922; Reichs-Marine-Amt charts Tit. XIV, 2, 2*a*, and 2*b* for 1920. All chart-values have been corrected to 1928.5 on account of secular-change rates indicated by the respective charts. The chart-differences are obtained by subtracting the chart-values from those determined on the *Carnegie*, east declination, north inclination, and horizontal intensity being reckoned as positive and west declination and south inclination as negative.

[b]Expressed in units of the third decimal C. G. S.

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Date	Latitude	Longitude east	*Carnegie*-values			Chart-differences[a]								
						Declination			Inclination			Hor. intensity[b]		
			D	*I*	*H*	Br.	Ger.	U. S.	Br.	Ger.	U. S.	Br.	Ger.	U. S.
1928	° ′	° ′	°	°	c.g.s.	°	°	°	°	°	°			
May 26	43 55 N	331 22	......	65.6 N	.199	.....	.....	.....	+0.5	+0.3	+0.6	−2	−3	−5
26	44 16 N	332 17	22.6W	......	......	+1.0	+0.9	+0.5	.....	.....	.....	.....	.....	.....
27	45 20 N	333 53	22.7W	......	......	+0.7	+0.8	+0.4	.....	.....	.....	.....	.....	.....
27	46 02 N	334 47	......	66.2 N	.195	.....	.....	.....	+0.4	+0.2	+0.3	−1	+2	−2
28	47 39 N	337 39	21.8W	......	......	+0.8	+1.1	+0.7	.....	.....	.....	.....	.....	.....
29	48 52 N	341 29	......	67.2 N	.184	.....	.....	.....	+0.8	+0.3	+0.4	−5	+2	−6
29	48 56 N	342 15	20.2W	......	......	+0.8	+0.7	+0.6	.....	.....	.....	.....	.....	.....
June 1	50 02 N	347 03	......	67.2 N	.183	.....	.....	.....	+0.7	+0.3	+0.4	−5	−2	−5
2	49 32 N	347 40	17.5W	......	......	+0.6	+0.5	+0.5	.....	.....	.....	.....	.....	.....
4	50 11 N	348 12	......	......	.183	.....	.....	.....	.....	.....	.....	−4	−2	−5
4	50 06 N	348 21	......	67.3 N	......	.....	.....	.....	+0.9	+0.5	+0.5	.....	.....	.....
4	49 44 N	348 39	17.4W	......	......	+0.5	+0.7	+0.5	.....	.....	.....	.....	.....	.....
5	50 01 N	349 23	17.6W	......	......	0.0	+0.3	+0.1	.....	.....	.....	.....	.....	.....
7	50 24 N	351 48	16.3W	......	......	+0.1	+0.7	+0.3	.....	.....	.....	.....	.....	.....
7	50 05 N	352 27	......	66.7 N	.186	.....	.....	.....	+0.7	+0.4	+0.1	−4	−1	−4
8	49 47 N	353 55	14.9W	......	......	+0.3	+0.9	+0.5	.....	.....	.....	.....	.....	.....
19[c]	50 30 N	359 17	......	......	.189	.....	.....	.....	.....	.....	.....	−1	0	−1
19	50 30 N	359 28	......	65.9 N	......	.....	.....	.....	+0.2	0.0	+0.3	.....	.....	.....
19	50 31 N	359 58	12.6W	......	......	−0.2	+0.1	+0.1	.....	.....	.....	.....	.....	.....
20	52 10 N	3 00	11.2W	......	......	+0.1	+0.3	+0.3	.....	.....	.....	.....	.....	.....
21	53 28 N	4 39	......	......	.176	.....	.....	.....	.....	.....	.....	−2	−3	−2
21	53 29 N	4 46	......	68.0 N	......	.....	.....	.....	+0.8	+0.3	+0.3	.....	.....	.....
July 8[d]	54 16 N	7 29	......	......	.174	.....	.....	.....	.....	.....	.....	−1	−2	−2
8	54 24 N	7 15	......	68.6 N	......	.....	.....	.....	+1.0	+0.3	+0.5	.....	.....	.....
8	54 31 N	7 02	9.2W	......	......	+0.3	+0.5	+0.3	.....	.....	.....	.....	.....	.....
9	55 54 N	4 26	10.7W	......	......	+0.5	+0.5	+0.8	.....	.....	.....	.....	.....	.....
10	57 15 N	3 10	11.8W	......	......	+0.3	+0.1	+0.7	.....	.....	.....	.....	.....	.....
10	58 23 N	2 07	......	71.1 N	.156	.....	.....	.....	+0.6	0.0	+0.5	0	0	−3
11	61 02 N	359 10	16.1W	......	......	−0.9	−0.1	−0.3	.....	.....	.....	.....	.....	.....
12	61 46 N	356 53	17.1W	......	......	−0.3	+0.3	+0.2	.....	.....	.....	.....	.....	.....
12	62 25 N	354 04	......	74.1 N	.138	.....	.....	.....	+0.8	+0.5	+0.6	−3	−3	−4
12	62 43 N	353 20	19.4W	......	......	+0.3	+0.7	+0.2	.....	.....	.....	.....	.....	.....
13	63 06 N	351 42	21.1W	......	......	−0.2	+0.3	−0.3	.....	.....	.....	.....	.....	.....
13	63 35 N	349 57	21.6W	......	......	+0.7	+1.1	+0.5	.....	.....	.....	.....	.....	.....
14	64 02 N	348 02	......	......	.126	.....	.....	.....	.....	.....	.....	−7	−6	−9
14	63 58 N	347 36	......	75.3 N	......	.....	.....	.....	+0.6	+0.3	+0.6	.....	.....	.....
15	63 36 N	345 48	24.9W	......	......	+0.4	+0.6	+0.3	.....	.....	.....	.....	.....	.....
15	63 26 N	344 51	......	74.7 N	.134	.....	.....	.....	+0.1	−0.2	+0.1	+1	+1	−1
16	63 17 N	343 20	26.8W	......	......	+0.2	+0.3	+0.1	.....	.....	.....	.....	.....	.....
17	62 53 N	341 20	......	74.9 N	.133	.....	.....	.....	+0.2	−0.1	+0.2	.....	.....	.....
17	62 36 N	340 58	28.3W	......	......	0.0	+0.1	−0.3	.....	.....	.....	0	0	−2

[c]The *Carnegie* was at Plymouth, England, during June 9 to 18, 1928.
[d]The *Carnegie* was at Hamburg, Germany, during June 22 to July 7, 1928.

Notes on Trip from Washington, D. C., to Newport News, Virginia, May 1 to 10, 1928

The seventh cruise of the *Carnegie* began when the vessel left her wharf at Washington, under tow, at 9^h May 1, 1928. Shortly after midnight on May 2 she came to anchor at the mouth of the St. Mary's River to await sunrise for beginning the swings in the lower reaches of the Potomac River. The day broke fair, and six swings under her own engine were made to detect any deviations in declination or horizontal intensity. Simultaneous observations were made ashore by the Department's field-parties, which had established numerous magnetic stations on both the Maryland and Virginia sides of the Potomac around the position previously selected for the swings. The vessel returned to same anchorage in the evening of May 2, and remained during May 3 and 4 while potential-gradient comparisons were being made with the shore-station. Experiments were also made to test the marine earth-inductor and the radio installation. On May 5 the *Carnegie* was swung again under her own engine in the morning to detect any deviations in dip and intensity, and then returned to anchorage to complete potential-gradient comparisons. Simultaneous shore-observations were made during all swings and comparisons. At $20^h\ 30^m$ anchor was weighed and the *Carnegie* proceeded to Newport News, where she arrived at 8^h May 6 for docking and adjusting the oscillator of the deep-sea sounding apparatus.

Leaving dry-dock at 11^h May 10, the *Carnegie* was towed out into Hampton Roads, and late in the afternoon cast off the tug and set sail while still in the entrance of Chesapeake Bay (see Plate I), taking a departure from Cape Henry at $18^h\ 20^m$.

Notes on Trip from Newport News, Virginia, to Plymouth, England, May 10 to June 8, 1928

Weather conditions were rather unfavorable throughout the entire time—strong winds, heavy seas, and cold and rainy weather. The course as planned was followed fairly well for the first two weeks, but during the last two weeks head-winds and baffling winds were experienced. The vessel was held off the entrance to the English Channel for ten days by easterly and southeasterly winds and gales.

Declination (D) observations with marine collimating-compass were made at 29 stations, and horizontal intensity (H) with deflector and inclination (I) with earth inductor at 12 stations.

Chart-corrections ranged from $+1°.7$ to $-1.°0$ in D, from $+0.002$ to -0.009 c.g.s. in H, and from $+0.°9$ to $-0.°7$ in I. All magnetic instruments worked well. The maximum range in the inclination for a single station did not exceed 30′ as determined with earth inductor 7, using improved gimbal-ring mounting (not gyro) and microammeter without amplification. At all but three stations experimental determinations of H were made with the same method; vertical intensity (Z) was determined also at a number of stations.

The atmospheric-electric program has been carried out as completely as was possible. The radioactive-content apparatus has not yet been put in operation. The masthead-mounting for the photographic potential-gradient electrograph has not been found practicable because of the great play of the masthead in moderate and rough weather. Experiments are being conducted to determine if this equipment may be used at the stern near the eye-reading potential-gradient apparatus.

Six ocean-stations for securing temperature and water-sample series were occupied, conditions of sea and weather not being favorable for stopping the vessel on other days. All the equipment, winch, water-bottles, and deep-sea reversing thermometers, both protected and unprotected, work excellently. The open glass protecting tubes on four of the unprotected thermometers were broken, due to the thermometer-frames being too small. These tubes will be replaced in Hamburg, the thermometers themselves being uninjured. The three water-bottles on the deeper end of the wire on one series were not reversed, owing to the messenger being obstructed by some fibrous organism which had become entangled with the wire. Some animal of the deep had fouled the wire. The unprotected thermometer, calibrated for pressure, gave excellent control of the actual depths reached. Usually, owing to a stiff breeze, the wire-angle at the surface was very large, so that some control of the depth was very necessary.

The tow-nets were operated at eight complete stations, and surface-tows were made at 50 stations. Whenever the vessel was hove to or under slow headway, advantage was taken of the opportunity to secure surface-tows and dip-up specimens with dip-nets. Many collections were made at night, using the under-water light. The large meter-nets were not used except on one or two occasions, awaiting the devising and constructing of heavier releasing devices.

The salinity-bridge has been in successful operation from the

first, and salinities are usually available on the day following the occupation of an ocean-station.

The depth-finder has been used at 57 stations. Unfortunately, it was not possible to check its accuracy with wire-soundings, but in shallow water the results agreed to within one fathom of the chart-values.

Daylight-contact with radio station *NKF* (U. S. Naval Research Laboratory at Anacostia, D. C.) failed early in the trip. It is hoped that a more extensive schedule, including one at night, may be arranged later. Good contact has been maintained with station *IMK* at Hartford, Conn., U. S. A., throughout the trip, with one or two exceptions.

The ship has been kept up in as good condition as was possible, in view of the almost continuous bad weather. The small engine and generator worked well, and frequent use was made of the main engine during calms and to get eastward against the head-winds. The new arrangements for life-boats were found to cause too heavy strain on the chart-room and new laboratories, due to lateral thrusts from life-boat platforms, and consequent flooding of the cabin and staterooms. The accumulation of water on the main deck naturally was troublesome.

Supports under the inboard ends of the cross-beams which support the boat-platforms to take the weight off the chart-room and other laboratories will be installed at Plymouth and Hamburg. The heavy weather also started the copper sheathing to peel off in many places along the water-line. The vessel will have to be drydocked in Hamburg to complete the necessary repairs. In general, the vessel labors and works less than heretofore, in spite of being very heavy and low in the water aft. The quarterdeck has been awash many times during the trip across, something which has happened very rarely in past cruises. The rigging has kept fairly taut and in good condition. One of the large bronze bolts holding the topgallant mast in place on the top of the foremast was carried away early in the trip.

After the ten-days' delay with head-winds, the vessel was within a few hours' sail of picking up the first landfall at Bishop Rock, Scilly Islands. Then it began to rain, fog and mist closed in, and it was necessary to stand off to sea again. After several hours, it cleared up enough to head for the light, which was picked up at midnight. A fine fair wind then held to within ten miles of Plymouth, when it began to rain, mist and fog set in, the wind

hauled ahead, and we were on the point of heading back to sea again, when the headland was sighted two miles west of Plymouth Harbor. We then took in squaresails, started the engine, and beat our way to port against a rising gale, with only one hour of daylight remaining. The pilot was found waiting inside the harbor when the vessel had already gained a safe position near the breakwater. In letting go the port anchor, the new cable was so stiff and hard and wet from continual bad weather that it kinked and could not be let out rapidly enough to fetch the vessel up against the gale. The starboard anchor was let go just in time to avoid danger, and the vessel remained at anchor until taken to the well-sheltered inner harbor the next morning. For the next 36 hours a terrific gale blew from southeast to southwest, which would have sent us hurrying back to sea again for another week if we had been lucky enough to weather the confines of the channel.

Notes on Trip from Plymouth, England, to Hamburg, Germany, June 18 to 22, 1928

The *Carnegie* left Plymouth at $16^h\ 30^m$, June 18, being towed 15 miles off shore until sails were set, and with a fair wind proceeded up the channel all night. The engine was operated the next day because of light winds and calm. During the night of June 19, the *Carnegie* passed through Dover Strait with favorable wind and tide; fortunately there was no fog, and conditions were excellent. Soon after leaving the Strait, the wind hauled ahead, however, and it was necessary to operate the engine practically continuously through the North Sea.

After making successful landfalls along the Dutch and German coasts approaching the Elbe River, and when within three hours' sail of the mouth of the river, fog and mist and rain set in, making it impossible to sight the two lightships which point the way to the mouth of the Elbe. By keeping on and watching for the traffic route as indicated by glimpses of steamers passing to southward in the mist, the ship gradually headed up against the strong flood-tide and finally made out the pilot-vessel during a temporary lifting of the fog. The engine again proved its value and assistance, taking the vessel up the river against head-winds and calms, until we met the tugboat (ordered from Hamburg the previous night) while passing Borkum Riff lightship.

Surface-tows were made and samples taken at 33 stations in the English Channel, Dover Strait, and the southern North Sea

to the mouth of the Elbe River, and analyzed for phosphates, *H*-ion concentration, and salinity. Two surface-tows were also made as the vessel proceeded up the Elbe River to Hamburg. Magnetic declination, inclination, and horizonal intensity were determined at two sea-stations between Plymouth and the mouth of the Elbe River.

Dr. H. U. Sverdrup, of the Geophysical Institute in Bergen, Norway, and Research Associate of the Department, was on the dock to meet the party, and it was a welcome sight to see the face of an old friend in a strange country. The *Carnegie* reached the dock at Hamburg June 22 at $19^h\ 30^m$, a little over four days out of Plymouth.

Notes on Trip from Hamburg, Germany, to Reykjavik, Iceland, July 7 to 20, 1928

The *Carnegie* left the gasoline wharf at Hamburg, Germany, about noon on July 7 under tow. When the mouth of the Elbe River was reached a strong head-wind was blowing, so it was necessary to retain the tugboat for a tow of 20 miles to sea to insure getting off shore safely. At $8^h\ 30^m$, July 8, the engine was started and the tow-line was cast off. By midnight it was possible to set the squaresails, so the engine was stopped and the vessel proceeded on course through the North Sea, making good progress on July 9, 10, and 11. The Shetland Islands were sighted on the afternoon of July 11 and the Faroes on the afternoon of July 12, both groups being passed to the northward.

Prevailing southwest winds prevented making the southward loop as planned between Iceland and the Faroes, and the *Carnegie* stood off to the northwest to cross the track of 1914 near the southeast corner of Iceland. This track was reached July 14, and then for six days head-winds were met as the vessel fought her way westward along the south coast of Iceland. The engine again proved its value, and was operated with the fore-and-aft sails as often as conditions were favorable for a total of 76 hours during six days. Without the engine it would not have been possible to make Reykjavik, and at one time it was seriously considered to proceed to St. Johns, Newfoundland, omitting Iceland. As the wind shifted only between northwest and southwest, it was necessary to tack or wear ship eleven times. Usually when trying to make a headland or to pass a definite and necessary point, the weather was bad and visibility was obscured by mist and rain,

making navigation difficult and exacting and entailing some risk.

The magnetic work was carried out as planned, enough clear weather being present to secure good series of declination-observations at eleven stations, and of horizontal-intensity and inclination-observations at six stations. Only two oceanographic stations were occupied, owing to strong winds and time required in tacking against head-winds. The anchorage at Reykjavik was reached at 8^h 30^m, July 20, the harbor being entered in the midst of rain squalls and low-hanging mist and fog.

Surface-tows were made and samples obtained at five stations. The depth-finder was used at forty stations.

Observations of all the atmospheric-electric elements, with the exception of radioactive content, were made whenever conditions permitted. Lack of time and adverse weather prevented getting the radioactive-content apparatus into working order. At Hamburg a stage was built on the stern rail to starboard of potential-gradient apparatus No. 2, and the photographic potential-gradient recorder was mounted thereon. The collector-rod of the latter was remodeled so as to allow the disc-collectors to project from the stern. Some very good results were obtained with this arrangement. On account of head-winds, hence the frequent necessity for running the main engine, some of the records do not represent normal air-conditions, but it is felt that the present location of the instrument is the most feasible one on the ship, and it is anticipated that reliable diurnal-variation data may now be obtained regularly. Eye-reading apparatus No. 2 gave trouble during the damp weather after leaving Hamburg, because of insulation of the sulphur-bearing insulators. These were recast at Reykjavik.

Dr. Kolhörster delivered the penetrating-radiation instrument after his design (Günther and Tegetmeyer No. 5503) in Hamburg, and daily intercomparisons between this instrument and penetrating-radiation apparatus No. 1 were made. There are some difficulties in using an instrument such as this, rigidly attached to a rolling ship and having coarse fibers widely separated and in constant and irregular motion. It is necessary to use a large initial potential (over 300 volts) and the time-interval for each observation must be at least one hour. The new instrument is to be recalibrated before leaving Reykjavik. After leaving Reykjavik it is intended to make diurnal-variation observations at least once each week of as many of the elements as the weather-conditions permit.

GEOPHYSICAL METHODS AS APPLIED IN THE STUDY OF GEOLOGICAL STRUCTURE[1]

THE RELATION OF THE MAGNETIC WORK OF THE UNITED STATES COAST AND GEODETIC SURVEY TO GEOPHYSICAL PROSPECTING METHODS[2]

By Daniel L. Hazard

Although the Coast and Geodetic Survey has never had funds available for an intensive study of the relation between underground geological formations and the distribution of the Earth's magnetism at the surface, nevertheless, in the execution of a magnetic survey of the United States, it has accumulated a large amount of valuable data which is available for those who may desire to make such a study.

The magnetic work of the Survey was begun as one of the essential operations in the making of navigational charts, and was later extended to meet the needs of the surveyor making or retracing compass-surveys. Both of these needs would have been met by the determination of the magnetic declination alone. It was recognized at the outset, however, that little progress could be made in a study of the nature of the Earth's magnetism based on a knowledge of only a single element, and the practice was adopted of determining the dip and horizontal intensity at the stations, as well as the declination. As a result of this wise policy, there are now available values of these three magnetic elements at about 5,000 places in the United States, most of them determined since 1900. From these the vertical intensity and total intensity can be readily computed.

In addition, observations have been repeated at intervals of about five years at a limited number of well-distributed stations, for the determination of the change of the Earth's magnetism with time, so that the results at all stations may be reduced to a common epoch. On the basis of these reduced values the distribution of the Earth's magnetism may be shown graphically by means of

[1]The following six papers were presented in a symposium, April 26, 1928, at Washington, D. C., on this subject at the joint meeting of the sections of Geodesy, of Seismology, and of Terrestrial Magnetism and Electricity of the American Geophysical Union at its ninth annual meeting.

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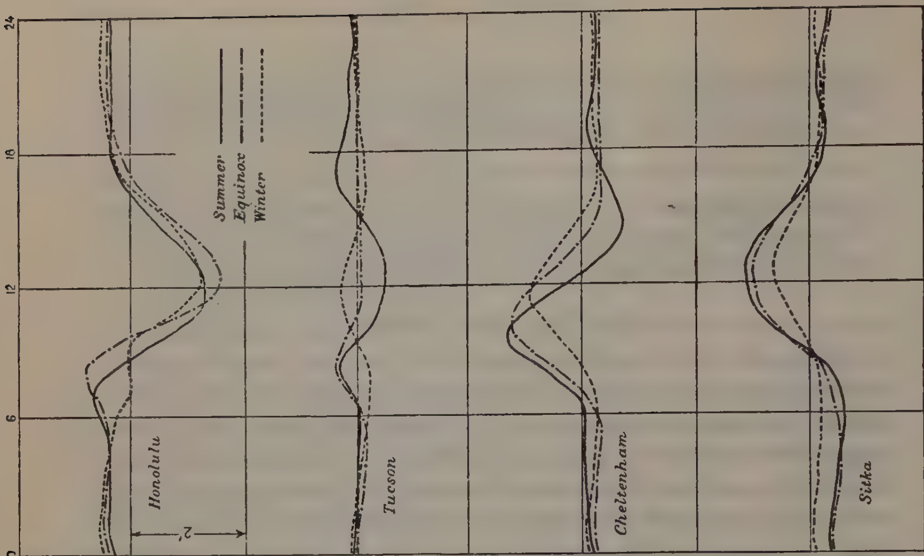

Fig. 2—Curves showing diurnal variation of dip

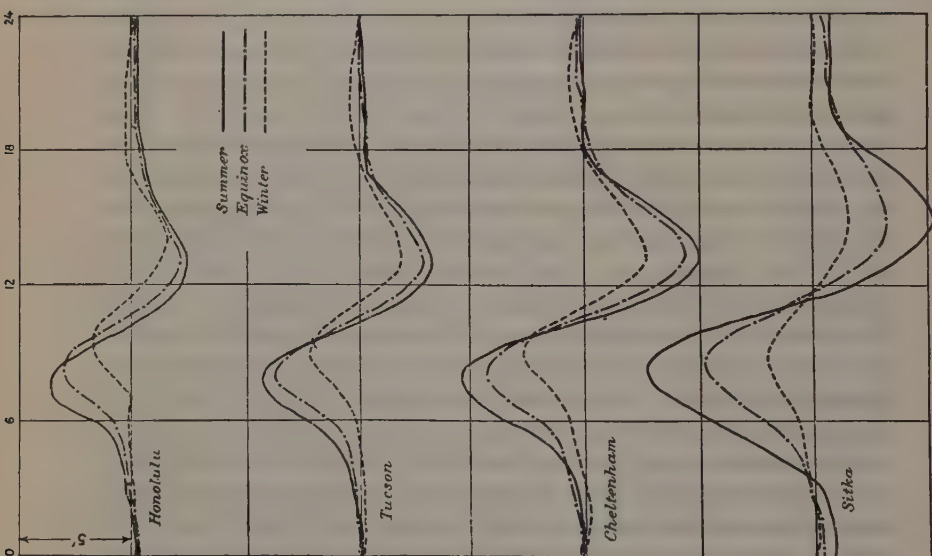

Fig. 1—Curves showing diurnal variation of declination

isomagnetic charts. This has been done for 1905, 1915, and 1925, the results for 1925 being still in manuscript form, however.

Magnetic stations thirty miles or so apart, as they are in the magnetic survey of the United States, cannot be expected to give very much information regarding small anomalous areas such as

are now being studied by various geophysical methods in Texas and adjoining states, but they may indicate regions where detailed surveys are most likely to prove fruitful, and they do serve to show the magnitude of the anomalies to be expected and provide absolute values of the magnetic elements to which to tie the usual relative results of the detailed surveys.

In the location and development of magnetic ore-bodies, the anomalies are large and satisfactory results can be obtained with rather crude instruments and methods. Where the anomalies to be expected are small, however, more sensitive instruments must be used, and many precautions must be taken to secure results of the necessary accuracy. As the Earth's magnetism is constantly fluctuating, it is important that the prospector using magnetic methods should know the magnitude and probably also the details of the fluctuations occurring during the progress of a particular survey.

The records of five widely distributed magnetic observatories operated by the Coast and Geodetic Survey furnish detailed information regarding these fluctuations, the large and irregular disturbances known as magnetic storms, which occur at practically the same time all over the Earth, and the comparatively regular diurnal-variation, which is a function of local mean time, varying, however, in amplitude and phase at different times of the year and in different parts of the Earth. From these records the prospector can determine to what extent the fluctuations must be taken into account in his observations, and whether he can get along with the approximate corrections which a distant observatory can supply, or must control his observations by operating a temporary observatory of his own. If he finds that the ordinary diurnal-variation is small enough to be neglected, he may still need a report from an observatory of the days on which magnetic storms occur of sufficient magnitude to vitiate his observations.

It may be helpful to indicate in a general way the magnitude of the daily fluctuations in the Earth's magnetic field and how great departures from normal or average conditions may be expected to occur. On inspecting the photographic records from an observatory the first impression is that irregular change is the predominant feature, one day's record differing from the next, sometimes to a marked degree. If the records for the less disturbed days are compared, however, it will be seen that there are certain general features which repeat themselves with considerable

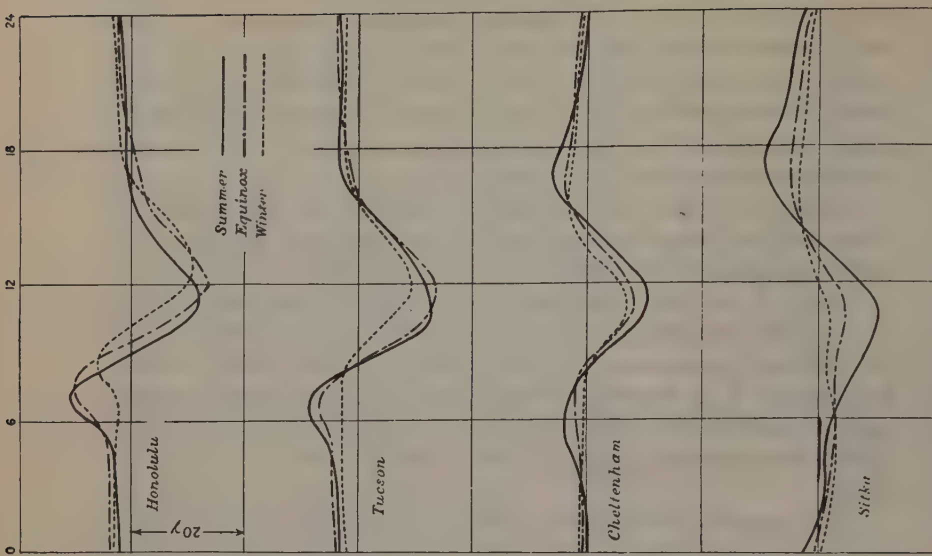

Fig. 4—Curves showing diurnal variation of vertical intensity

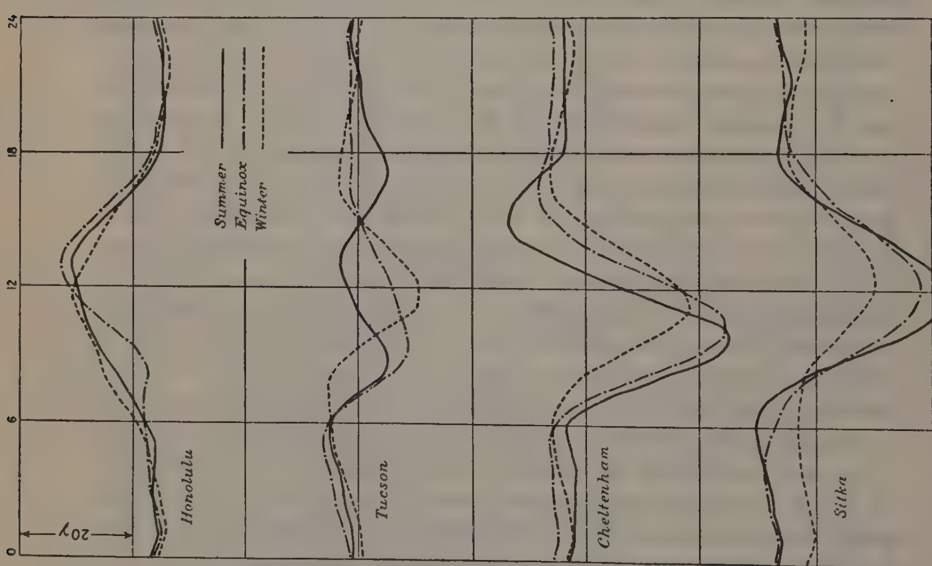

Fig. 3—Curves showing diurnal variation of horizontal intensity

regularity, maximum and minimum values of fairly definite amounts occurring at fairly definite times of the day. By combining month by month the hourly values for those less disturbed days, diurnal-variation tables may be prepared showing how great a departure from the daily mean may be expected at any hour of the day on days of that type.

From a study of such tables for a number of observatories for a series of years it will be found: (1) That there are marked differences in the diurnal-variation at observatories in different latitudes, both as to amplitude and phase; (2) that the diurnal variation is different for different months of the year, there being change in the time of occurrence of the extremes as well as in the amplitude. The change from month to month is so gradual, however, that it is sufficient for most purposes to combine the months into three groups of four each, November, December, January, and February, classed as winter months, when the days are short (in the Northern Hemisphere); May, June, July, and August as summer, when the days are long; March, April, September, and October, grouped around the equinoxes. It will be found that for any one month or group of months there is little change in the diurnal variation from year to year, except that the amplitude is usually greater in years of maximum sunspots than in years of minimum sunspots.

Figures illustrate the features noted under (1) and (2). Each curve represents the mean of ten days a month for about ten years, or about 400 days in all. It will be seen that in each case the principal part of the variation occurs during the daylight-hours, indicating strongly that it is related in some way to the position of the Sun above the horizon.

The declination-curves are all of the same general character with an easterly extreme three or four hours before noon and a westerly extreme one or two hours after noon. The range and the time between the extremes is less in winter than in summer. The greatest summer-range and the least winter-range occur at the most northerly station, Sitka, which suggests a connection with the length of day.

In the case of dip the whole character of the curves changes from station to station. At Honolulu the predominant feature is a minimum about noon, whereas at Sitka it is a maximum about noon. At Cheltenham the curve for summer shows a maximum in the forenoon and a minimum in the afternoon, whereas for the rest of the year there is only the maximum, as at Sitka. At Tucson the variation is very small and irregular, representing a transition between the opposite conditions existing at the stations to the north and south.

The diurnal variation of horizontal intensity shows the same general characteristics as that of dip, except that where the dip shows a maximum the horizontal intensity shows a minimum and vice-versa.

In the case of vertical intensity the range decreases with increase of latitude. All four stations show a decided minimum about noon, and all except Sitka show a maximum early in the forenoon. At Sitka the maximum occurs in the late afternoon, and this maximum appears at Cheltenham also, somewhat more pronounced than the one in the morning.

It will be seen that the amplitude of the diurnal variation, based on the less-disturbed days, is not large, of the order of ten minutes of arc in declination, two minutes of arc in dip, and twenty-five gammas (one gamma = 0.00001 c. g. s. unit) in horizontal intensity and vertical intensity. The process of combining a large number of days on which the extreme values are not strictly in phase necessarily results in a certain amount of flattening of the mean curve, so that the range of the means is less than the mean of the ranges on the individual days. There may, therefore, be days included in the mean having a range double that indicated in the diagrams.

When it comes to the irregular fluctuations, departures from the daily mean five times as great as those indicated in the diagrams are not infrequent, and at the time of magnetic storms they are sometimes ten times as great, of the order of one to two degrees in declination, and 200 to 500 gammas in horizontal intensity and vertical intensity. At such times the change is sometimes very rapid. These large disturbances occur at irregular intervals, may last one day or several, and their coming cannot be predicted. Hence, the prospector using magnetic methods, if he is aiming at an accuracy of one part in a thousand, should at least know on what days magnetic disturbances occur, and repeat or use with caution observations made on those days; or, better, should maintain a temporary observatory near the field of operations, making observations in it coincident with those in the field. He can then correct his field-observations for any changes in the Earth's magnetism which may have occurred while they were being made.

U. S. Coast and Geodetic Survey,
Washington, D. C.

GEOPHYSICAL METHODS OF PROSPECTING, WITH SPECIAL REFERENCE TO MAGNETIC, RADIOACTIVE, AND ELECTRIC METHODS[1]

By C. A. Heiland

Geophysical methods of prospecting may be divided into two groups of a different character, as indicated in Tables 1 and 2. The first group comprises methods (for example, gravitational) by which direct effects of subterranean inhomogeneities are observed. The second group consists of procedures (for example, seismic, magnetic, radioactive, and electric) whereby artificial fields of force are produced and their distortion by subterranean bodies of different physical properties is measured. This paper is to discuss briefly the magnetic, the radioactive, and the electric methods of prospecting.

(*I*) *The magnetic method*—This is probably the oldest geophysical method. It is based upon the fact that the various formations and minerals in the ground have different magnetic permeabilities. The minerals which rank highest in their magnetic effects are magnetite, ilmenite, pyrrhotite, and hematite. Hence, magnetic prospecting is applicable in mining to the discovery of iron-ore deposits. Greater still is its importance in oil geology, if the oil-bearing structures are associated with igneous rocks. Igneous rocks contain always a certain amount of magnetite. Also non-magnetic ores may be located by magnetic prospecting if they are associated with magnetic structures or magnetic minerals; non-magnetic formations may be found (salt-domes) if they are sufficiently diamagnetic or surrounded by more magnetic formations. Noble metals (gold and platinum) can generally be located in placer-deposits, because they have been deposited together with magnetite.

There is a great variety of magnetic instruments, but at present there are only a few types which are in actual use. For crude work, such as applied on iron-ore deposits, the dip needle and the Thomson-Thalén magnetometer are used. For oil exploration, the vertical and horizontal field-balances of Ad. Schmidt are in most widespread use. However, earth inductors are beginning to be employed.

The theory of the effect of subterranean bodies of given dimen-

[1]Abstract of the paper given April 26, 1928, before the American Geophysical Union which presented merely a general survey of the present stage of development of these methods, without attempting to present anything new beyond the material already published.

Table 1—*Summary of geophysical methods of prospecting by measurements of direct effects of structures or deposits*

Measurements of		Apparatus	Subject of measurements	Physical effect of disturbance	Applications
Field of gravity	Pendulum-measurements	Pendulum-apparatus	Relative force of gravity	Maximum value of g over heavy mass	Major mass or structural features
	Torsion-balance measurements	Torsion-balance	Gravity-gradients and curvature-values	Gradient at its maximum and variation of the main direction of curvature above or near edges	Ore-deposits, salt-domes, buried structures, unconformities, the relief of buried terrain, and, by indirect application, mineral oil
Magnetic field		Portable theodolite-magnetometers	Declination, horizontal intensity, inclination	Declination, horizontal intensity, and inclination maximum and minimum over edges	Magnetite, pyrrhotite, hematite, limonite, salt-ridges, buried igneous masses, and, by indirect application, mineral oil and placer gold
		Local variometers or magnetometers	Vertical intensity	Vertical-intensity maximum over south-magnetic mass and minimum over north-magnetic mass	
			Horizontal intensity, declination	See above	
		Inductors	Inclination, horizontal intensity, vertical intensity	See above	
		Variation instruments	Declination, horizontal intensity, vertical intensity		Elimination of variations
Use of natural earth-currents (electro-chemical action)		Electrodes with galvanometer or potentiometer	Equipotential lines	Disturbance most frequently at center of curves (negative potential)	Most sulphide ores
Thermic action		Maximum and recording thermometers	Thermal gradient	Increase of rate of temperature-gradient near the source of heat or structural uplifts	Mineral-oil structures and certain ores in wells and shafts
Radioactivity		Electroscope and ionization-chamber	Relative ionization	Increased radioactivity near disturbances	Faults and mineral dikes (clay and oil horizons in wells and shafts)

TABLE 2—*Summary of geophysical methods of prospecting by measurements of reaction of structures and deposits to external forces of artificial character*

Measurements of		Apparatus		Subject of measurements	Physical effect of disturbance	Applications
Reaction to elastic waves	Acoustic measurements	Oscillators, microphones		Travel-times over the direct path, refraction and reflection	Form of time-graphs	Ores
	Seismic measurements	Seismographs		Travel-time (speed of propagation)	Form of time-graphs	Ores, salt-domes, and buried structures
Reaction to electrical currents	Simple resistance-measurements	Circuit and galvanometer		Resistance of circuit	Current in the case of conductive connection, variation of resistance	Connection between accumulation of brine and offshot-veins of ore, subterranean unconformities
	Laying out an artificial electrical field	Direct current and alternating current	Direct-current and alternating-current generator, primary and secondary electrodes, telephones, galvanometer	Equipotential lines	Conductor forces equipotential lines apart	Most sulphide ores, coal, saline solutions (good conductors), mineral oil (? indirectly), buried structures, stratification
		Alternating current only	Primary electrodes (galvanic), reception-coil, telephones	Direction and intensity of combined primary and secondary electromagnetic field and phase-angle	Plane of coil when sound is at minimum is perpendicular to the direction of current-lines attracted by conductor	
		Alternating current only	Insulated primary (inductive) loop and reception-coil	Intensity of secondary field-components	*Z*-component at maximum above center, *H*-component maximum near edges of conductor	
Reaction to wireless waves	Absorption-method	Transmitter and receiver		Nature of reception	With conductor between transmitter and receiver no reception	In salt-mines, accumulation of brine
	Reflection-methods, primary field shielded	Transmitter and receiver		Path and direction of waves	Reflection by conductors	In dry districts—sulphide ores, water; elsewhere—accumulation of brine, cementation
	Interference-methods	Transmitter and receiver or transmitter only		Variation of reception-strength with the wave-length	Secondary wave produced by reflection or induction interferes with primary wave indicating depth and direction	
	Capacity-methods	Transmitter		Variation in capacity, that is, in frequency and damping	Substances with high dielectric constants increase capacity (good conductors increase capacity and damping)	

sions on the magnetic intensities, primarily vertical and horizontal, has been investigated by various authors, as for instance, Thalén, Dahlblom, Uhlich, Haanel, Smyth, Carlheim-Gyllenskoeld, Hotchkiss, Walker, Bahurin, Lasareff, Eötvös, Haalck, Griesser, and recently by Koenigsberger.[2]

Very extensive work is being done by oil companies in this country in locating the contours of granite-ridges, which are associated with the occurrence of oil in West Texas, Kansas, Oklahoma, Colorado. The magnetic work on salt-domes on the Gulf Coast has been virtually abandoned. The magnetometer is also applied to oil prospecting in Mexico by locating volcanic plugs and dikes. Magnetic "gold finding" is going on at the placers in Alaska, British Columbia, and California. Magnetic measurements on iron-ore deposits have been made successfully in New York, New Jersey, the Lake Superior region, Colorado, and Canada.

(II) Radioactive methods—Besides the location of radioactive minerals, these methods have been applied for the detection of faults and mineral dikes. The increased radioactivity of the former is probably due to the facilitated circulation of air and water carrying radium-emanation. When the minerals crystallized out of the solutions, circulating along the fault, thus forming a dike, the abundance of radioactive minerals was retained.

The effect of such faults at a distance is small and does not penetrate through a cover which is thicker than several meters. Yet it is advantageous to apply this method in suitable localities, because it permits finding zones of mineralization and faults, the latter being especially important for determining appropriate locations for dams.

The methods which may be used in radio-active prospecting are quite variable. (1) One way is to take samples of the ground at certain intervals and to determine their radioactivity by chemical analysis or by the use of an ionization-chamber. (2) Another is to determine the radioactivity of air sealed in holes which have been made in the ground some time before. (3) An ionization-chamber without bottom may be used, being placed on the ground at intervals. (4) The penetrating radiation of the radioactive soil may be measured at intervals with a completely shielded chamber. (5) An ionization-chamber on tripod may be used, into which the radioactive air of the surface soil is pumped from a hole made in the ground. The last is the method which is now in most widespread use. No measurements have been published in this country

[2]Beitr. Geophysik, Leipzig, Bd. 19, Heft 2/3, 1928 (241-291).

as yet. In Europe successful application of the radioactive method has been made for the location of faults (especially for water-dam projects) and mineral dikes. The relative radioactivities observed at the stations along the surface are plotted as a curve. From the shape of such a curve conclusions may be derived as to the thickness of the overlying strata (J. Koenigsberger).

(*III*) *Electric methods*—The successful application of electric methods is made possible if the formations sought differ sufficiently in their electric conductivity from the surrounding rocks. Thus, ore-bodies are frequently good conductors, especially sulphide ores. Although the chief application of electric methods is confined to mining, they are useful to some extent in oil geology. General structural conclusions may be frequently drawn from the results. There are not only highly insulating formations (such as salt-domes) which are associated with oil, but the structures are frequently, due to water in the cleavage planes, better conductors in the direction of bedding than at right-angles to it.

Electric prospecting for ore has been very successful in this continent, especially all over Canada, in the Lake Superior copper region, in Newfoundland, in New Mexico, in Arizona, etc. The electric work in oil geology has been done primarily in Texas, Mexico, and California without, however, having such an obvious success as the electric prospecting for ore.

The theory of the electric effects of subterranean conductive bodies has been investigated by Schlumberger, Lundberg, Sundberg, Gish, and Jakosky for their individual methods.

There is a great variety of electric methods of prospecting. The space available for this abstract does not permit giving details of these, but from the following classification the reader may readily visualize the various principles applied and their interrelation. For more complete and descriptive information the various publications of the American Institute of Mining and Metallurgical Engineers, Class *L*, by Lundberg, Sundberg, Leonardon, Kelly, Jakosky, Mason, Weaver, and Rooney should be consulted.

The electric methods may be classified as follows:

(*A*) Methods measuring electric fields supplied by the ore-bodies through electro-chemical action.

(*B*) Methods measuring modifications of electric currents or electric fields, or of radiations artificially applied to the ground, including: (I) Methods using direct determinations of resistivity as in Gish's method; (II) methods measuring the distortion of an electric

field; and (III) methods determining the distortion of radio waves through observations of absorption, reflection, and capacity.

Under Classification (*B*-II) there are the methods using: (1) Direct current, as in Schlumberger's method, to determine equipotential lines and potential profiles; or (2) alternating current, either by (*a*) primary field supplied galvanically by contact to the ground, or (*b*) primary field supplied inductively by insulated loops or coils. The method (2-*a*) includes distortion of field as determined by contact of secondary electrodes with ground for measurements of equipotential lines and potential profiles, as employed by Lundberg, and as determined inductively by using coils to obtain the direction of the electromagnetic field of the ground-currents (Elbof) or to obtain the intensity of the electromagnetic ground-field (Lundberg). The method (2-*b*) includes distortion of field determined by contact of secondary electrodes with the ground (a method not in use) and inductively by using coils to obtain the direction of the electromagnetic ground-field (as in Mason's method and the Radiore method) or to obtain the intensity of the electromagnetic ground-field (Sundberg's method).

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DEPTHS OF GROUND-WATER AND OTHER SUBSURFACE FEATURES INDICATED BY EARTH-RESISTIVITY SURVEYS

BY O. H. GISH

In the course of the earth-resistivity surveys made as part of the program for earth-current investigations by the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, it has become evident that the method used is capable of locating and ascertaining the depth of various subsurface geological features.

In the paper presented the general features of the method previously described elsewhere[1] were briefly reviewed. The manner of adjustmg and using the specially designed commutator so as to obtain measurements under steady current-conditions; that is, obtaining the potential measurements over a portion of the "square-wave" cycle well removed from the make and the break, was explained.

The justification for the rule used in estimating from resistivity-

[1] O. H. GISH AND W. J. ROONEY, *Terr. Mag.*, v. 30, 1925 (161-188) and v. 32, 1927 (97-126).

data the depth to a subsurface discontinuity was outlined. This rule is that *the body of earth affecting a measurement extends to a depth equal to the distance between adjacent electrodes and to an equivalent distance laterally.* It can be readily ascertained that for the simple case of a horizontal surface-stratum of depth equal to the electrode-separation and which overlies a deep stratum of different resistivity the potential difference as measured by this method differs from that which would exist if the upper stratum extended to an infinite depth by less than 20 per cent even in those extreme cases where the resistivities of the two strata differ by many orders of magnitude. The rule accordingly holds in so far as it concerns practical needs.

Seven cases in which the depth to a change in structure as indicated by resistivity-surveys had been checked by independent methods were illustrated and discussed. The depths varied from 10 feet to 300 feet. One survey indicating a change at a depth of 1,200 feet, but for which there are as yet no data to check against, was also shown. These data have been published elsewhere.[2]

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THE EÖTVÖS TORSION-BALANCE METHOD OF MAPPING GEOLOGICAL STRUCTURE[1]

By Donald C. Barton

The Eötvös torsion-balance measures two quantities: the differential curvature of the level (equipotential) surfaces at the point of observation, and the rate of the horizontal variation of gravity at that point. From the rate of variation of gravity, the variation of gravity throughout the area of a survey can be calculated if the stations are close enough together. In areas of no deformation, normally, the horizontal variation of density is slight, but the vertical variation of density is considerable, and usually in the direction of relatively light unconsolidated Tertiaries at the surface through denser and denser Mesozoic rocks, and yet denser Paleozoic rocks, to the dense crystallines of the basement. Structural deformation therefore causes a deformation of the uniform distribution of density. The resulting irregularities of mass produce anomalies in the distribution of gradient and differential curvature values. With a slight reservation, it may be said that

[2]See foot-note 1; also W. J. Rooney and O. H. Gish, *Terr. Mag.*, v. 32, 1927 (49-63).

[1]The complete paper is published as a part of the article under the same title printed as A. I. M. E. Technical Publication No. 50 (Feb., 1928).

differently shaped bodies of greater or less density than the surrounding medium produce different patterns of gradient and differential curvature anomalies, and that different types of geologic structure produce recognizably different anomalies. From the results of torsion-balance surveys it is possible to come to certain qualitative conclusions in regard to the subsurface structure, and in some cases to make definite quantitative calculations of what it is. Like all geologic methods, this method is not a panacea for working geologic structure. There are situations where it works brilliantly, other situations where it is of value, and yet other situations where it is of no value.

The original and still the most fundamental references on the Eötvös torsion-balance are:

ROLAND V. EÖTVÖS. Untersuchungen über Gravitation und Erdmagnetismus. Ann. der Phys. und Chem., N. F., 59 (1896).

Bestimmung der Gradienten der Schwerkraft und ihrer Niveauflächen mit Hilfe der Drehwage. Verh. d. XV. allgemeinen Konferenz d. internationalen Erdmessung in Budapest, 1906.

Geodätische Arbeiten in Ungarn, besonders über Beobachtungen mit der Drehwage. Verh. d. XVI. allgemeinen Konferenz d. internationalen Erdmessung in London u. Cambridge, 1909.

Die Niveauflächen und die Gradienten der Schwerkraft, am Balatonsee. Budapest, 1908.

The more important papers in English are:

STEPHEN RYBAR. The Eötvös torsion-balance and its application to the finding of mineral deposits. Econ. Geol., 18:639-662 (1923).

H. SHAW AND E. LANCASTER-JONES. The Eötvös torsion-balance. Proc. Phys. Soc. of London, 35:151-165 (1923).

The application of the Eötvös torsion-balance to the investigation of local gravitational fields. Ibid., 36 (1923).

The Eötvös torsion-balance and its application to the location of minerals. Mining Magazine, London, 18-26, 86-93 (Jan.-Feb., 1925).

W. HERBERT FORDHAM. Oil-finding by geophysical methods J. Inst. Pet. Tech., London (October, 1925). [Also reprinted and distributed by L. Oertling Ltd., London.]

ANONYMOUS. The Eötvös torsion-balance. A pamphlet to be used as a manual with the Oertling torsion-balance. L. Oertling Ltd., London, 1925.

H. SHAW AND E. LANCASTER-JONES. Locating minerals and petroleum. Being a series of articles on the theory and practical use of the Eötvös torsion-balance, reprinted from the Mining Magazine, London (April to July, 1927). L. Oertling Ltd., London, 1927.

D. C. BARTON. The Eötvös torsion-balance method of mapping geologic structure. A. I. M. E. Tech. Paper No. 50 (Feb., 1928).

E. LANCASTER-JONES. The computation of Eötvös gravity-effects. A. I. M. E. Tech. Paper No. 75 (Feb., 1928).

H. SHAW. Gravity-surveying in Great Britain. A. I. M. E. Tech. Paper No. 79 (March, 1928).

P. W. GEORGE. Experiments with the Eötvös torsion-balance in the tristate zinc and lead district. A. I. M. E. Tech. Paper No. 65 (Feb., 1928).

C. A. HEILAND. Schweydar-Bamberg types of Eötvös torsion-balance. Bull. Am. Ass. Pet. Geol., 10:1201-1209 (1926).

A cartographic correction for the Eötvös torsion-balance. A. I. M. E. Tech. Paper No. 52 (Feb., 1928).

TRANSMISSION OF ELASTIC WAVES THROUGH SURFACE-ROCKS

By Roy W. Goranson

Elastic disturbances are propagated through rock in a definite determinable manner. The path and speed of the waves set up are dependent on the elastic constants of the medium traversed. A knowledge of the subsurface structure of the Earth's crust is given from the data furnished by seismograph-records of earthquake disturbances for distances up to a thousand kilometers, corresponding to depths of something over one hundred kilometers. Such rock-structures, when reproduced on a small scale, give similar seismograph-records. This is shown for the case of salt-domes, the location of which is important in oil geology.

The elastic waves traveling through rock-material resulting from a sudden shock may be divided into two main types, if we except the surface-waves, namely, the longitudinal or compressional type of waves, which are analogous to sound-waves, and the transverse or distortional type of waves, which are analogous to water-waves. Along any path, then, there will be a transverse and a longitudinal wave. Of these two the longitudinal is about 1.5 times faster than the transverse wave.

The complete picture is not so simple as this, for at each change in the rock-character reflection and refraction occur and at such boundaries each of these waves is itself broken up into a transverse and longitudinal wave. Further complications are introduced because of the fact that rock is not an isotropic medium. I shall here discuss only the longitudinal type of wave.

A time-distance curve for a certain type of wave is obtained by plotting its time of arrival against the distance it travels as measured along the Earth's surface. Time and distance are measured from the epicentre as origin. The epicentre is the point on the Earth's surface either coinciding with or lying vertically above the focus or point of initiation of the impulse.

From the derived mathematical relations and our experimentally determined physical constants of rocks we can, for any reduced time-distance curve, i. e., a curve for which the focus coincides with the epicentre, determine the underground rock-structure.

I shall first present an interpretation of the rock-structure of the Earth's crust from seismograph-records of earthquake shocks.

Figure 1 shows a reduced time-distance curve of the near-

surface longitudinal earthquake waves. The data from which this curve was plotted are such that no one set of records will furnish a complete reduced time-distance curve, and thus it is necessary to construct it from many sets of records. The resulting plot is not everything that can be desired, since many curves could be juggled to fit the data equally well. We are greatly in need of more data with a higher degree of accuracy, and until the data are obtained our knowledge of the Earth's crust must remain in a rather hazy state.

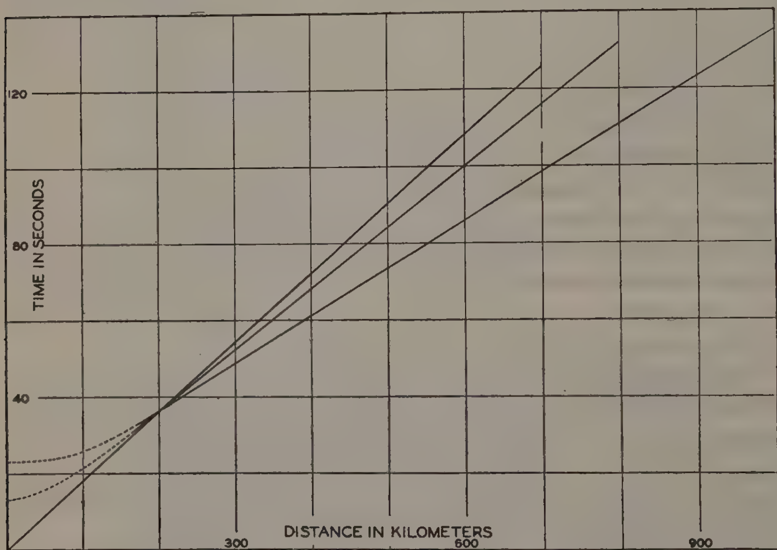
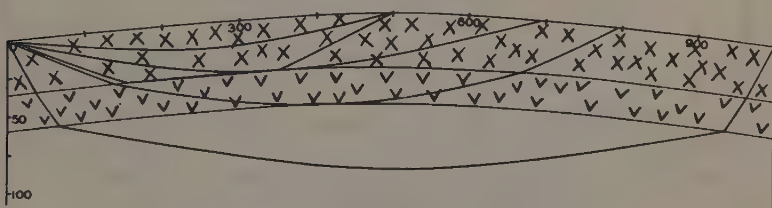


FIG. 1—Time-distance curve of near-surface longitudinal earthquake waves

There are three sharp breaks or discontinuities shown in this curve. One portion of the curve goes from the origin to a distance of 700 km. The other two portions start at a little less than 200-km distance, one stopping at 800 km, the other continuing on beyond 1,000 km, with a surface-velocity greater than either of the other two. The far ends of the first two portions are not definitely determined. In the next time-distance curve additional data taken from Harold Jeffreys' writings are introduced which place these terminations at greater epicentral distances.

There is a definite straightforward mathematical procedure for obtaining the interpretation of these curves. Figure 2 gives the interpretation of the previous curve. The portion of the curve which starts at the origin and has the least surface-velocity,

corresponds to waves traveling in the x-stippled layer, which is a granitic layer about 35 km thick. The first discontinuity in the time-distance curve corresponds to the lower boundary of this layer. The second portion of the curve corresponds to the arrivals of waves which travel through a lower layer about 15 km thick, and is shown as a v-stippled band. The rock in this layer has the physical characteristics of a basalt. The second discontinuity in the curve corresponds to the lower boundary of this v-stippled layer, which is about 60-km depth. The third portion of the curve corresponds to the arrivals of waves which travel in a still lower layer. The rock in this lowest layer has the characteristics of a peridotitic rock. The data are not accurate enough to fix these layers at the depths I have indicated. These figures can therefore be only approximations.



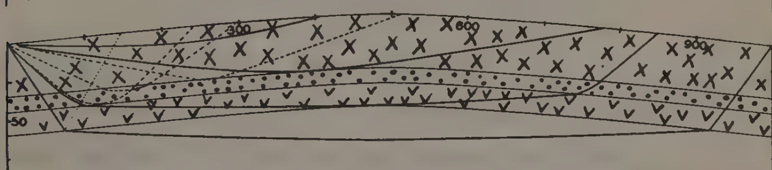


FIG. 2—Interpretation of time-distance curves of Fig. 1, boundaries between the rock-layers as sharp discontinuities

FIG. 3—Interpretation of time-distance curves of Fig. 1, transition zone being assumed to occur between the first and second layers

In the interpretation just presented the boundaries between the rock-layers were put in as sharp discontinuities. This need not be true, for if a continuous transition-zone of, say, 10 km occurred between the pairs of layers a similar time-distance curve with sharp discontinuous breaks would still occur, and this is true irrespective of the wave-length.

In Figure 3 such a transition zone is assumed to occur between the first and second layers. This zone is shown as dot-stippled. Moreover, the velocity is assumed to vary as the square of the depth which gives circular paths in this zone.

Pseudo-reflections are denoted as dashed lines. The time-

distance curve from such a rock-structure is shown in Figure 4. This curve is similar to that shown previously. The difference in the slopes of the curves is due merely to the fact that slightly different data were used in this calculation. The dashed lines represent the lines of arrival of the reflected and pseudo-reflected waves.

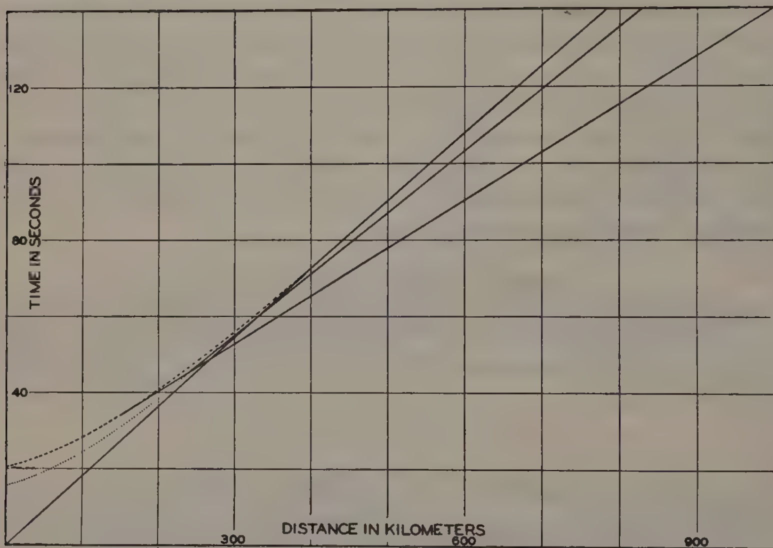


FIG. 4—Time-distance curve for a rock structure

The only difference between the two graphs is that the dotted line shown in Figure 4 is non-existent in this graph. This part of the curve is, however, never actually observed on seismograph-records.

The remainder of this paper is an attempt to indicate the correspondence between time-distance curves obtained from rock-structures on the scale of the Earth's crust and similar rock-structures extending to depths of only a hundred or so meters.

In recent years artificial shocks have been produced and seismograph-records made of the times of arrival of the wave-motion produced. The time-distance curves obtained in this way are a valuable indication of the underground structure. One use to which this has been put is in the location of salt-domes. The average velocity of the longitudinal wave in sediments is about 2 km/sec, in rock-salt, 4.4 km/sec. Two possible salt-domes have been reproduced in Figure 5, one with a circular top and the other

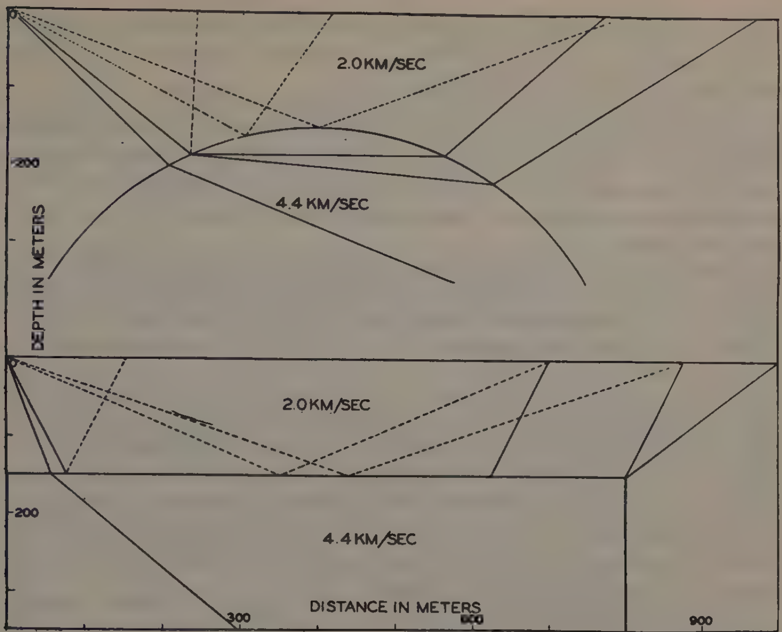


FIG. 5—Time-distance curves for the case of two possible salt-domes, one with a circular and the other with a flat top

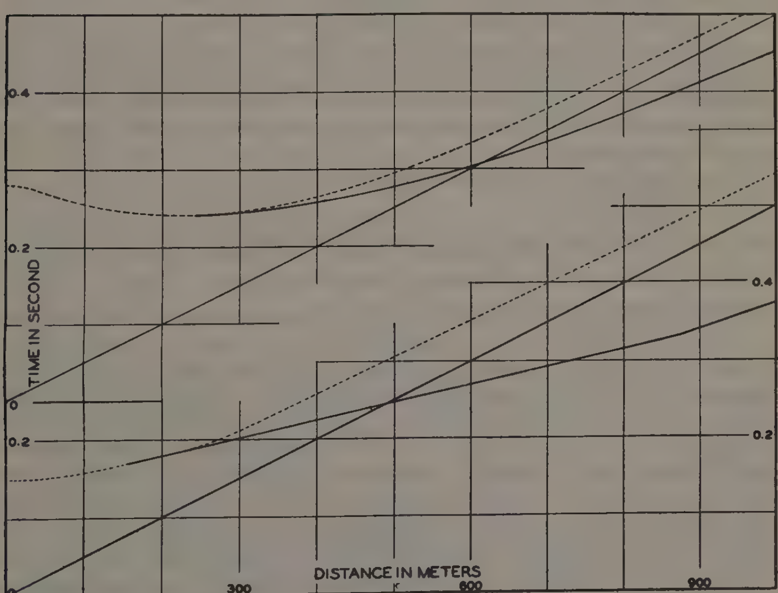


FIG. 6—Time-distance curves calculated for structures of Fig. 5

with a flat top. In this case the velocity in sediments is assumed to be constant. This is not so, but I have no exact data on the variation of velocity with depth.

The dotted lines represent rays reflected from the surface of the dome. Here the critical angle for the angle of incidence is about 27 degrees. All rays making an angle greater than 27 degrees with the normal to the surface of the dome are reflected to the surface, those making an angle less than 27 degrees are refracted into the dome.

Since only one discontinuous surface has been assumed, there will be only one discontinuity in the time-distance curve. Figure 6 gives the time-distance curves calculated for these two structures. Here the upper one corresponds to the circular dome, the lower one to the flat-topped dome.

The portion of the curve that leaves the origin denotes the times of arrival of the wave-impulses traveling through sediments. The other portion denotes the times of arrival of the waves that travel part of the way in the dome. These curves will asymptotically approach parallelism with the upper curve. The dashed lines denote the times of arrival of the reflected waves. These reflected waves are rarely observed on seismograph-records, but, none the less, they must be present.

Since the time-interval between the arrivals of these impulses reaches a maximum of about a tenth of a second for these near-surface structures, the times must be determined very accurately in order to obtain a true interpretation of the data.

Thus we see that this curious phenomenon of discontinuous breaks in the time-distance curves of earthquake waves is here reproduced for salt-domes in sediments. Moreover this will occur whenever such a change in character of the rock takes place that the velocity in the lower layer is greater than in the upper one.

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THE ADVANCE OF AN EARTHQUAKE DISTURBANCE

By Harry Fielding Reid

The simplest form of the solution of the general elastic equation of wave-motion is $y = \sin\,(2\pi/\lambda)\,(x - vt)$, where λ is the wave-length and v the velocity; x and t are the distance and time, respectively. This equation extends from minus infinity to plus infinity, both in distance and in time. The conditions introduced to determine the movement of a seismograph acted upon by such a disturbance, though mathematically correct, lead to physical impossibilities. Another solution of the general equation was suggested which gives the disturbance a definite front, where the medium is at rest in its position of equilibrium, and does not require the introduction of impulsive velocities, as, for instance, in Love's treatment of wave-motion.

VARIATIONS OF SOLAR RADIATION[1]

By C. G. Abbot

It will be recalled that while observations of the solar constant of radiation by the fundamental method of Langley, which involves measurements on clear days from low to high Sun, are made by the Smithsonian Institution under many types of sky as a basis, and later occasionally as check observations, most of the daily solar-constant work is carried on by the abbreviated method depending upon measurements of the brightness of the sky around the Sun as an index of the atmospheric transparency. Inasmuch as the energy-curves at the Earth's surface are greatly affected by the water-vapor bands, and it is impossible to know just where the smooth curves would run over the tops of these wide bands in the bolographs, there is always a possibility that minute errors in the final results, either by the long or by the short method, depending upon the prevailing atmospheric humidity, will persist.

In order to eliminate these systematic errors it is necessary to collect a long series of observations made under comparable conditions of apparatus, and box them with reference to the quantity of precipitable water contained in the atmosphere on the days of observation to determine the residual correction as a function of the prevailing humidity. In doing this, allowance has to be made for the variability of the Sun during a long series of observations extending perhaps over several years, else effects due to solar changes would be confused with those really due to the atmosphere. In former discussions a combination of the observations made in the northern and southern hemispheres has been employed to fix these allowances for solar variation. This procedure, while theoretically sound, has been objected to by critics, as tending to take away the independence of stations, and accordingly we have substituted another method based upon the principle of selected pyrheliometry, so that each station now stands by itself, absolutely independent of all others.

The results from Mount Montezuma as now being published daily on the weather map of the United States Weather Bureau, are regarded as final and definitive. We have tested them again and again, and find no evidence that atmospheric conditions now influence them.

[1]This and the following paper by F. E. Fowle were presented in a symposium on interrelations between the sea and the atmosphere and the effect of these relations on weather and climate, April 26, 1928, at Washington, D. C., at the joint meeting of the sections of Meteorology and of Oceanography of the American Geophysical Union at its ninth annual meeting under the subheading "Problems related to solar radiation."

The results from Table Mountain, however, when compared with those from Mount Montezuma, while showing a fair agreement, gave evidence of a yearly march and also of daily irregularities. My colleague, Mr. Fowle, having suggested that no allowance had been made for the variations of atmospheric ozone, has discussed the observations at both stations. He has found that although the influence of ozone upon the results at Mount Montezuma is negligible, it is by no means so at Table Mountain, and that the whole yearly range disclosed is due to the variations of atmospheric ozone at that station. Although the work is not quite finished, it also seems probable that the divergences of *daily* observations will be largely reduced by the application of the corrections for the effect of ozone.

These results are quite in harmony with the recent work of Dobson, who finds that all European stations show large changes in atmospheric ozone, whereas our station at Mount Montezuma, which he provided with apparatus of exactly the same type as used in Europe, showed a very small and constant atmospheric ozone-content. Thus it is not surprising that Table Mountain, in California, should show the ozone-effect, while Mount Montezuma, in Chile, does not.

These re-reductions and corrections completed, it now appears that the North and South American stations have agreed very closely indeed in their testimony of the variability of the Sun. Furthermore, that variability, although clearly shown, has been much smaller in the years 1924 to 1928 than we had formerly been inclined to expect. Indeed, if the results of the observations of 1926 and 1927 had alone been available as evidence—that is, if our whole campaign had commenced in 1926 instead of in 1902—it is likely that we should have concluded that the variation of the Sun was too small to warrant further continuance of our difficult and costly investigations of it.

However, all the observations at Mount Wilson, Calama, Montezuma, and Harqua Hala unite to show that a change of several per cent accompanies the march of the sunspot-cycle, values of two to three per cent higher occurring at times of maximum sunspots. Also the comparative analyses of the Montezuma observations with South American observations of the last six or eight years indicate pretty clearly certain regular periodicities of 25⅔, 15, and 11 months. They also indicate irregular fluctuations of the order of one per cent or more, running their course in intervals of a few days. These several types of variation seem interesting enough and likely to be fruitful enough to warrant the continuation of the work with greatest possible precision for a number of years to come, in order that the scientific men of the next generation may be in position to determine what importance on terrestrial concerns is to be attached to the variation of the Sun.

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Washington, D. C.

OZONE IN THE NORTHERN AND SOUTHERN HEMISPHERES[1]

By F. E. Fowle

Measuring the output of radiation from the Sun encounters greater difficulties when attempted in the northern hemisphere (Mt. Wilson, Harqua Hala, Table Mountain) than in the southern (Calama and Montezuma, Chile). May not this be due to some asymmetry between atmospheric conditions above these two sets of stations which spoils the apparently excellent skies of such a station as Table Mountain, California?

Supposing that something coming from the Sun causes a change in the upper air, either in the form of electric particles or as ionization due to ultra-violet light, then the resulting particles, electrically polarized, under the influence of the Earth's magnetic field, might very probably drift unsymmetrically toward one of the poles of the Earth.

Ozone can be formed by the action upon oxygen of ultra-violet light between the wave-lengths 0.120 to 0.180μ. It is decomposed by light of wave-lengths between 0.200 and 0.300μ. Hence, a layer of ozone might exist from this cause high up in the atmosphere where the former effect preponderated. Lower down as the energy of the shorter wave-lengths of the Sun's energy became more rapidly weakened than the longer, a place would be reached where the decomposition-effect would exceed the generation, and no ozone would be found.

A considerable depletion by ozone of the incoming energy from the Sun has been found by several writers.[2] Laboratory measures of this absorption by ozone show that the amount necessary to cause that observed in the Sun's spectrum should be about 0.3 cm. at atmospheric pressure. If this amount of ozone were uniformly distributed, there would be required per unit volume about 4×10^{-7} by volume, or 60 mg per 100 kg of air by weight.[3] Lespieau finds at the surface of the Earth a concentration equivalent to only one-twentieth this amount, and practically the same proportion at a height of five kilometers (Mt. Blanc).[4]

An experiment suggested by Fabry and Buisson was carried

[1]Published by permission of the Secretary of the Smithsonian Institution.

[2]Fabry, Proc. Phys. Soc., v. 39, 1926; Cabannes et Dufay, J. de Phys. et le Radium, v. 7. 1926 (257).

[3]Fabry, l. c.

[4]Lespieau, Bull. soc. chim. de France, v. 35, 1906 (616).

out by Strutt in 1918. It showed that the mercury-line at 0.2536μ could be transmitted horizontally through 6.5 kilometers of air. If the ozone causing the absorption in the solar spectrum were distributed uniformly through the air this should transmit only

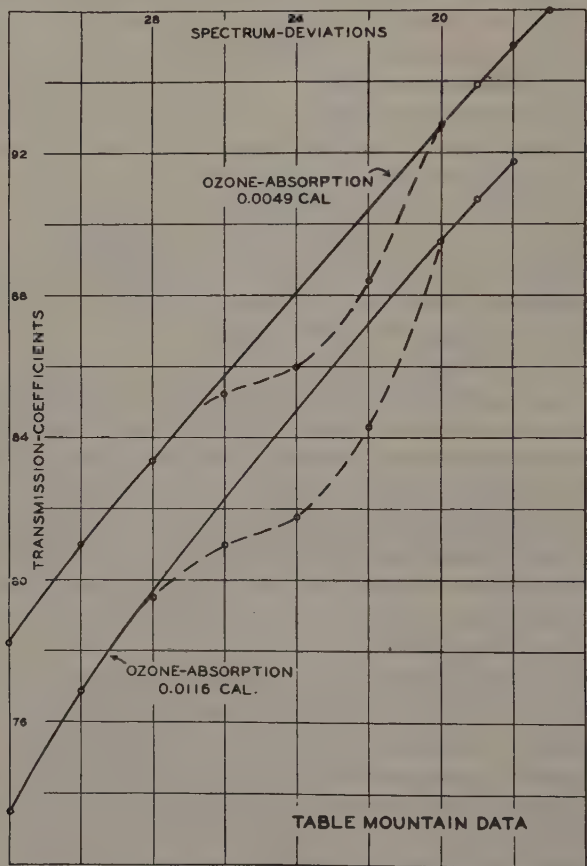

FIG. 1—Specimen plots for Table Mountain, California, to obtain measures of ozone-absorption, observed atmospheric transmission-coefficients plotted against spectrum-deviations

10^{-33} of the radiation at this wave-length. The ozone causing the absorption in the solar spectrum should therefore be found at a considerable altitude, and Cabannes and Dufay have estimated this altitude at about 50 kilometers.[5]

Cabannes and Dufay have utilized the dry-air coefficients of

[5]CABANNES ET DUFAY, J. de Phys. et le Radium, v. 8, 1927 (125).

transparency for the Earth's atmosphere published by the present writer[6] in the region of the Chappuis absorption-band of ozone in the yellow to measure the amount and variation from time to time of atmospheric ozone. Dobson has made similar measures, using a photographic method and the violet bands.[7]

The following measures of ozone are given in somewhat different units They indicate the amount of radiation cut out in the Chappuis band from the incoming radiation. A loss of 0.01 calory is equivalent to a layer somewhat less than 4 mm of ozone at atmospheric pressure.

Figure 1 indicates the appearance of the plots used to obtain the measures of ozone-absorption. The observed atmospheric transmission-coefficients for each day are plotted against the spectrum-deviations as abscissae.

Figure 2 shows the results for the separate days, expressed in units of 0.0001 calory per minute per square centimeter absorbed from the radiation of the zenith Sun. Attention is drawn to two characteristics of this figure: Firstly, at Table Mountain high values in the early part of the two years shown fall toward a minimum in November; and secondly, considerably smaller values obtain above Montezuma.

Figure 3 shows monthly means of the same quantities. Here is shown in more marked manner the same features. Above Montezuma, as may be noted from the two lower curves, there is an average absorption of about 0.004 calory, with no marked seasonal variation certainly during 1927. These figures are less accurate than for Table Mountain, because of smaller bands and less accurate observations. Above Table Mountain the seasonal change is very marked. The range is considerable, from about 0.013 down to about 0.004 calory (Fig. 2). The Montezuma observations are comparatively few in number, whereas those at Table Mountain number about 200.

Dobson's means are given for several stations of northwestern Europe. They are given in cm of ozone at atmospheric pressure. They show the same seasonal change indicated for Table Mountain.

Ozone is of interest to at least three branches of science: (*a*) To meteorology, in that it absorbs a very appreciable amount of the incoming radiation from the Sun, both in the violet and in the yellow band, and this in amounts varying from day to day. The

[6]FOWLE, Astroph. J. v. 40, 1914 (435); CABANNES ET DUFAY, J. de Phys. et le Radium, v. 8, 1927 (353).

[7]DOBSON, HARRISON, LAWRENCE, Proc. R. Soc., v. 110, 1926 (660); v. 114, 1927 (521).

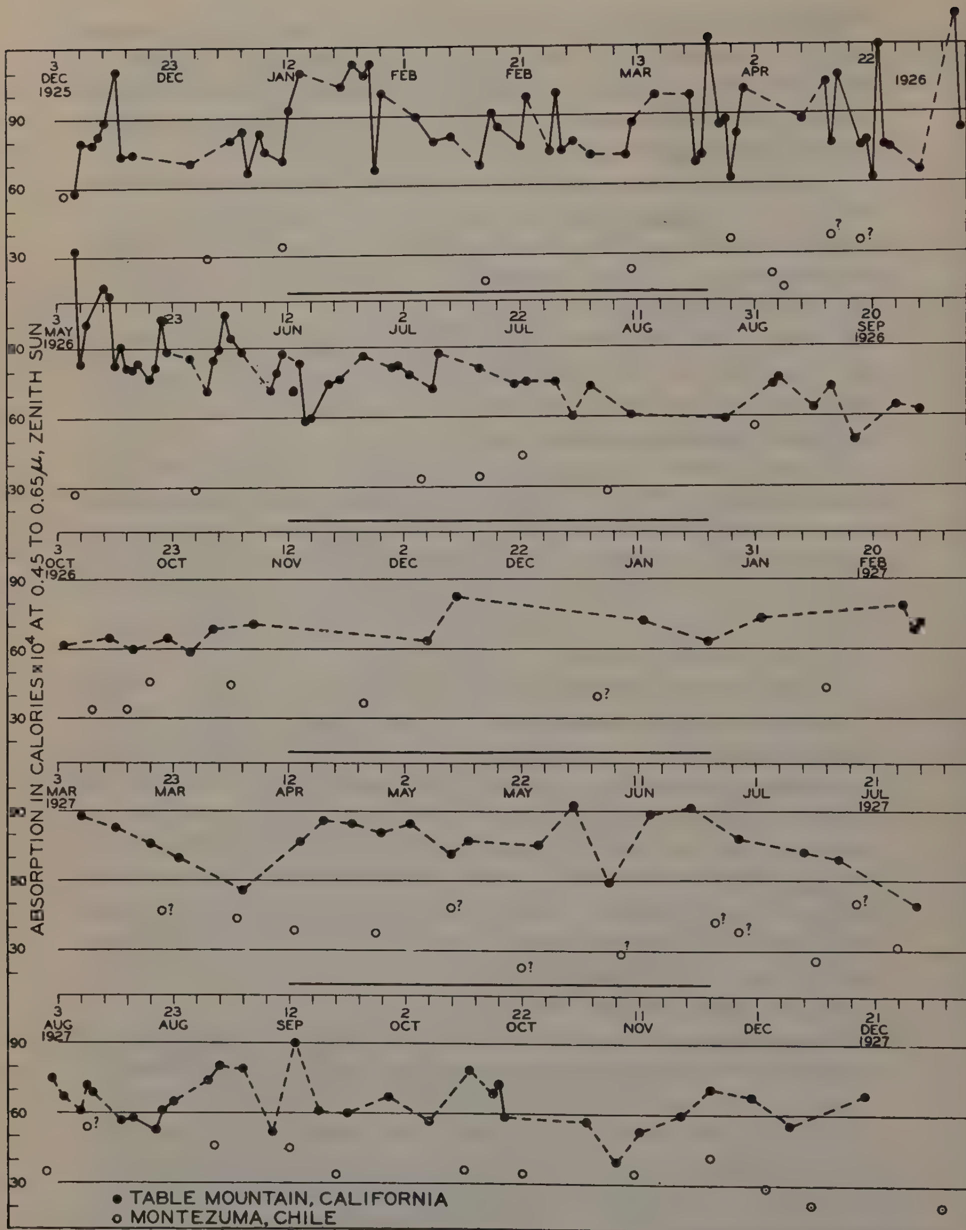

Fig. 2—Daily values of ozone-absorption from the radiation of the zenith Sun expressed in units of 0.0001 calory per minute per square cm for Table Mountain, California, and Montezuma, Chile, 1926 to 1927

band in the infra-red acts as a blanket to the outgoing radiation from the Earth for wave-lengths for which the atmosphere would otherwise be very transparent. (*b*) To astrophysics, in that it is another phenomenon leading to some insight into solar changes, as will be presently indicated. (*c*) To terrestrial magnetism and

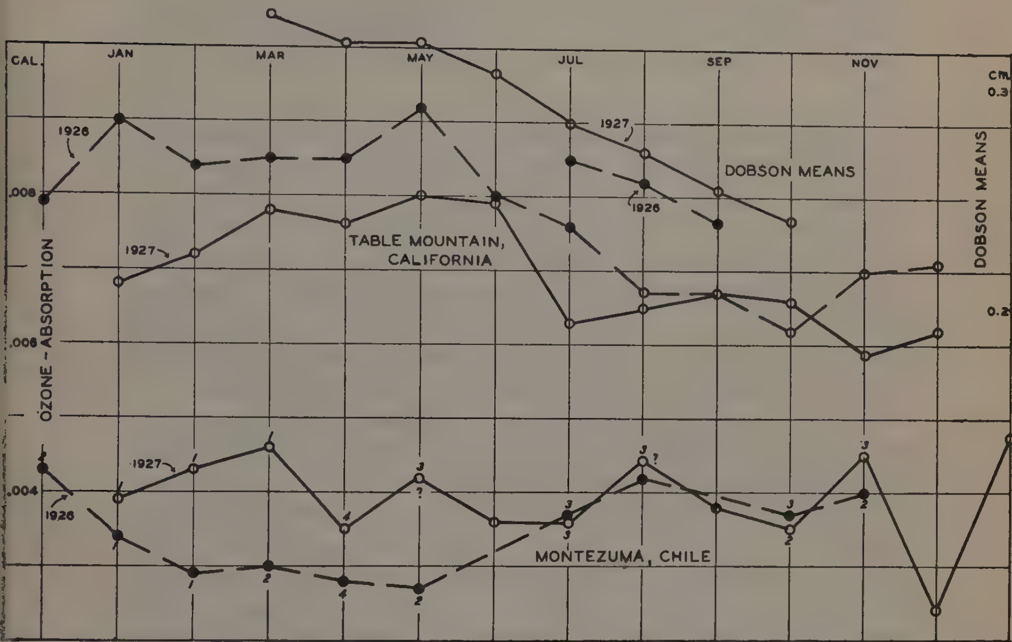

Fig. 3—Monthly means of ozone-absorption at Table Mountain, California, and Montezuma, Chile, 1926 to 1927, and Dobson's means for stations of northwestern Europe, July to September 1926 and March to October 1927

atmospheric electricity, because here we have a conducting layer, very probably of greater intensity in the sunlight hemisphere, and therefore practically rotating about the magnet formed by the Earth. Pertinent to this aspect is the following quotation[8] from Chapman's "The evidence of terrestrial magnetism for the existence of highly ionized regions in the upper atmosphere."

"The conclusions relative to the ionization of the upper atmosphere, which can be drawn from the evidence . . . of terrestrial magnetism, may be summed up as follows: There are two independent regions of high conductivity, ionized by independent solar agencies. One of these regions is a layer extending nearly or quite over the Earth; its conductivity is greatest where the Sun's zenith-distance is the least, and therefore it varies throughout the day and night at

[8]Chapman, Proc. Phys. Soc., v. 37, 1925 (38D).

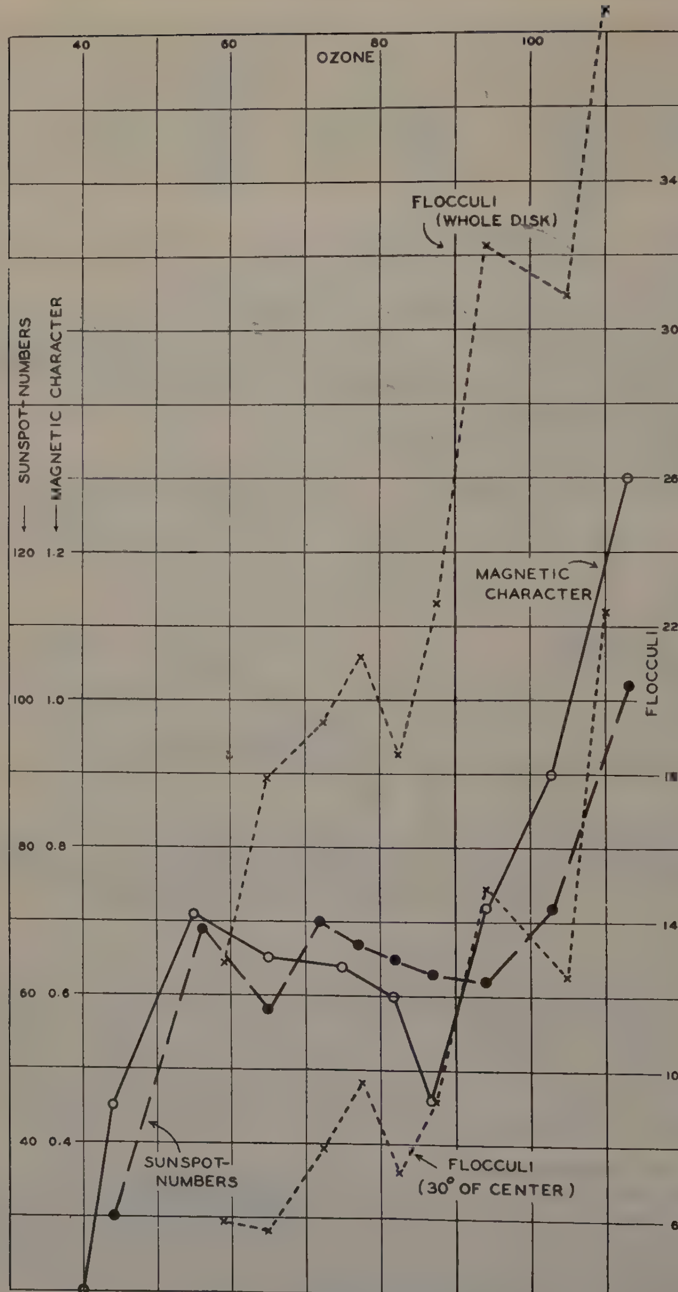

Fig. 4—Preliminary graph showing possible connection of ozone with magnetic character of day at De Bilt, Wolfer sunspot-numbers, and flocculi-area

any one station; when the station is in the sunlit hemisphere the conductivity is much greater than during the night hours. The average conductivity of this layer is comparable with that of a layer of copper, under ordinary conditions, one meter thick. The conductivity increases considerably from sunspot minimum to sunspot maximum. The distribution of conductivity in this layer suggests that the ionizing agent is ultra-violet radiation; it seems likely that the ionization is associated with the production of the layer of ozone which is known from the work of Fowler and Rayleigh to exist in the upper atmosphere. Consideration of absorption-bands of ultra-violet radiation indicates a height of about 40 or 50 kilometers for this layer. The magnetic evidence, so far as the theory is developed at present, does not suffice to indicate the height of the layer."

Figure 4 shows a preliminary attempt to study the possible connection of ozone (plotted as abscissæ) with the magnetic character of the day (De Bilt), the sunspot-numbers (Wolfer) and the area of the Sun covered by flocculi (both total area of disk and the area of the central 30°, del Ebro) plotted as ordinates. Each quantity shows a relationship, although the relationship with the total area of the Sun's disk covered with flocculi seems the most definite. The flocculi are bright hydrogen and calcium clouds high up in the Sun's atmosphere.

Summary—There is a comparatively small and apparently constant amount of ozone above the Chilean solar station of the Smithsonian Institution. Above Table Mountain it exists in an amount capable of exercising a considerable disturbing effect upon the incoming solar radiation. There is above Table Mountain a distinct seasonal variation for the two years shown (1926 and 1927), the absorption being greatest in the early months of the year, reaching a minimum along the early part of November for the two years stated. The amount of ozone above Table Mountain shows some relationship between the magnetic character of the day, the total spottedness, and a very decided relationship with the number of flocculi over the whole disk.

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REVIEWS AND ABSTRACTS

(See also pages 164 and 172)

Gunn, Ross: *The diamagnetic layer of the Earth's atmosphere and its relation to the diurnal variation of terrestrial magnetism.* Phys. Rev., Menasha, Wis., vol. 32, No. 1, 1928, pp. 133-141.

Balfour Stewart's theory of the diurnal variation of the Earth's magnetic field requires a serious modification as a result of the considerations presented in this paper. It is shown that large circulating currents of the type suggested by Stewart and investigated by Schuster and Chapman are impossible. The electrical conductivity of the atmosphere is shown to be very anisotropic in the important highly ionized regions. The considerations of Hulburt form the basis for this conclusion. Namely, Hulburt showed that the number of electrons or ions in the region of short free path is too small to account for the observed magnetic variations. Gunn shows that the upper and more highly ionized regions may account for the magnetic phenomena. The explanation, however, is quite different in its details from that of Stewart. The highly ionized portions of the atmosphere are very rarefied.

The magnetic field of the Earth curves the paths of electrons and ions and makes them travel in helical paths. In the important regions of the atmosphere, situated at an altitude of about 140 km., an electron may perform 3,000 revolutions before colliding, and a heavy ion makes usually at least two revolutions in its free path. An externally applied electric field is therefore ineffective in producing a current unless the field is directed along the Earth's magnetic field. An acceleration given to an electron at right-angles to the magnetic field only makes the electron revolve about the field somewhat faster, but does not produce a systematic drift of the electron.

All the calculations performed on the assumption of an isotropic conductivity of the upper atmosphere are therefore held to be erroneous by Gunn. Instead, he investigates the effects at the Earth's surface which are produced by the electrons and ions of the upper atmosphere. He finds, following the standard treatment of diamagnetic properties of materials, that the action of rarefied regions is that of a diamagnetic body. Its magnetization produces a magnetic field at the Earth's surface. During the day the ionization is large. The diamagnetic effects are therefore large also. A large effect at the Earth's surface is produced near noon. The variation of this effect with latitude is investigated. The computed and observed results for the horizontal intensity are shown in the accompanying figures 2 and 3 of the paper. The maximum number of ions of all kinds per cc is computed and found to be approximately 5×10^{10}. This agrees with radio evidence. The semidiurnal component of the diurnal variation is also investigated, but not very fully.

The main contribution is the emphasis on the inapplicability of calculations based on the assumption of uniform conductivity and the successful representation of the observed variation with latitude of the maximum variation of the horizontal component.

G. Breit

A NEW METHOD OF MARKING TIME ON MAGNETOGRAMS[1]

By H. E. McComb

Abstract—A new method of marking time on magnetograms consists essentially in increasing the width of the slit in front of the light source for a few seconds each hour. The resulting marks are short, black lines on all base-lines and curves. The slits are cut in an extension of the armature of a very sensitive relay which is operated by an independent clock.

In studying the problem of more suitable time-marks on magnetograms, it occurred to the writer that in addition to the usual time-breaks on the base-lines, it would be well to provide some means of indicating the identical hourly marks on the curves, but without loss of record and without errors due to so-called "overlap." Several schemes were tried, among which was one in which a segment of a long-focus lens was attached to the hand of a clock, the lens eclipsing a portion of the light from the slit of the magnetograph-lantern every hour. The result was a short faint line intersecting, almost at right-angles, all base-lines and curves every hour. The difficulties of keeping the mechanism in proper adjustment prohibited its use in routine operation, however.

The second design tried has many advantages and, therefore, is described in detail. The apparatus consists essentially of a narrow slit in a strip of thin brass attached to the armature of a very sensitive relay, mounted directly in front of the magnetograph-lantern. Light from the lantern passes through this slit, and is brought to focus in the usual manner on the magnetogram except during the interval required for the hourly marks. A clock, independent of the driving mechanism, closes a circuit through the relay for ten seconds each hour and the slit is displaced about two millimeters, or until light passing through it does not fall upon the variometer-mirrors. A portion of the thin brass strip is cut away so as to permit light to pass through a wider slit for the ten seconds required to produce the hourly marks. The effect of a wide slit in continuous operation would be wide base-lines and curves on the photographic record, but if exposed for only a few seconds the result is only a small segment of this line on all base-lines and curves, its intensity depending not only upon the intensity of the light-source, but upon the duration of the exposure. A sample magnetogram recorded at the Cheltenham Magnetic Observatory is shown in Figure 1.

The relay of the telephone type (Graybar Electric Company, No. G-11), is wound to a resistance of 1,500 ohms, and operates positively at a terminal potential of four to five volts, so that the operating current is very feeble. The axis of the coil is mounted

[1]Published by permission of the Director of the United States Ccast and Geodetic Survey.

vertically, but even in the horizontal position the effect of its field during the ten-second intervals is too small to affect the horizontal-intensity variometer, and it is so far from the vertical-intensity variometer that its effect is not apparent on any of the records.

In addition to its use as a device for marking time on the magnetograms, it may be operated at any time from any convenient place and for any duration by simply shunting the mechanism on the clock which closes the circuit hourly. Under best conditions a faint time-mark can be made by a two-second or three-second exposure. These special time-marks can be distinguished from the hourly marks quite readily on account of their density.

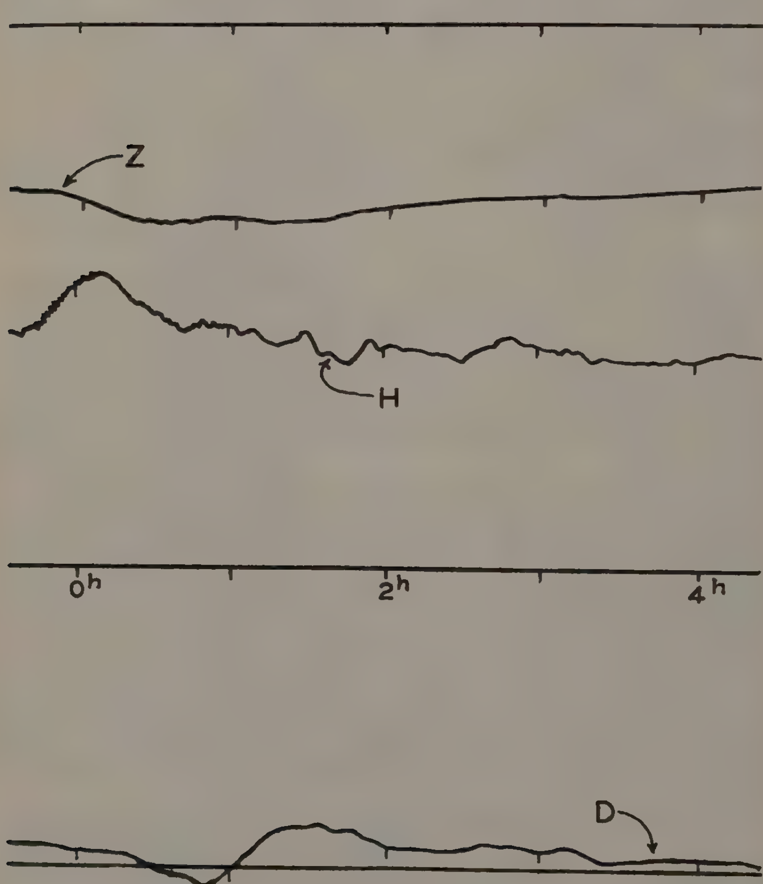

FIG. 1—Specimen magnetogram recorded at the Cheltenham Magnetic Observatory, June 3, 1928. (Scale-values: *D*, 1.′00 per mm; *H*, 1.85 gamma per mm; *Z*, 4.02 gammas per mm)

Thus, if a faint mark is produced at the beginning and another at the end of a set of absolute observations, the segment of the curve between the marks is the segment to be used in base-line computations for the observations made during this interval. There is no chance for error in getting the correct segment of the curve, provided, of course, the circuit is closed at the proper times. The use of artificial breaks for base-line observations has been in use for several years at the Honolulu Magnetic Observatory, and was inaugurated at San Juan Magnetic Observatory in January, 1928; but in these cases the light-source is either interrupted or eclipsed for one minute before and after the absolute observations, which results in some loss of record, of course. It is believed that the time-marks described here are more satisfactory.

As the marks are put on the magnetogram from an independent clock, it is possible to regulate the time-marking clock to a greater degree of accuracy than in the older types, in which the shutter is operated by the mechanism which drives the drum. It is believed that this method of marking time may be applied successfully to seismograms.

U. S. Coast and Geodetic Survey,
Washington, D. C.

PROVISIONAL SUNSPOT-NUMBERS FOR JUNE TO AUGUST, 1928

(Dependent alone on observations at Zürich Observatory)

By A. Wolfer

Day	June	July	August	Day	June	July	August
1	134	125	107	16	55	145	76
2	133	135	116	17	64	133	58
3	110	133	126	18	62	118	41
4	100	88	100	19	94	124	53
5	98	59	80	20	63	129	58
6	90	52	67	21	89	127	71
7	95	...	79	22	109	114	79
8	74	97	59	23	131	77	101
9	43	91	59	24	145	54	94
10	32	85	80	25	154	60	101
11	24	69	73	26	134	66	112
12	7	127	74	27	145	66	110
13	29	131	90	28	126	76	...
14	25	132	89	29	134	98	...
15	43	149	73	30	114	97	84
				31		105	80

Mean for June (30 days): 88.5.
Mean for July (30 days): 102.1.
Mean for August (29 days): 82.4.

AURORAL OBSERVATIONS, RADIO RECEPTION, AND MAGNETIC CONDITIONS AT THE SITKA MAGNETIC OBSERVATORY, AUGUST 1927 TO JUNE 1928[1]

By Franklin P. Ulrich

This report is a continuation[2] of the investigation, begun in 1923, of the relation between aurora and the Earth's magnetic field and of the effect of the aurora and magnetic conditions upon radio reception.

The program of the work has been divided into four parts: (*a*) The observation of the aurora at the Sitka Magnetic Observatory with a comparison of the Earth's magnetic field; (*b*) reports of aurora observed at various radio stations throughout Alaska; (*c*) a record of the daily reception of radio at Sitka and Fort Yukon, with a comparison of the magnetic conditions, and (*d*) a log of the auroral frequency.

Instruments and methods—The instruments and methods as outlined in the report for 1924 to 1925 were used during these observations. At Fort Yukon the radio receiver used for broadcast reception was a superheterodyne set with nine tubes. At Sitka the broadcast reception was received with an eight-tube superheterodyne, and the time-signals were received with a three-tube honeycomb-coil set. The time-signals at 8^h and 18^h were received from Annapolis; at 11^h and 21^h, from Mare Island, and at 15^h from Honolulu. All time was reduced to standard 135th meridian time, west.

In the observations and reports of aurora and radio reception the magnetic character of day is designated by the usual numbers of 0, 1, and 2. It applies not to the whole day for which the number is given, but for that portion during which the observations were taken.

Summary of results—As in former years, all of the observations are summarized, with deductions based on all of the reports and a comparison of similar observations for preceding years. This includes a comparison of the different phases of the aurora and the magnetic conditions, the effect of aurora on radio reception, the relation between the Earth's magnetism and radio reception, and a summation of auroral frequency.

Comparison of auroral character and magnetic conditions—No pulsations, draperies, or coronas were observed during the past year. Rays during aurora were observed 16 times, and during these times declination (D) was increasing 6 and decreasing 10 times; horizontal intensity (H) was increasing 4 and decreasing 12 times, and vertical intensity (Z) was increasing 9 and decreasing 7 times. As in former years the motion of the magnetic elements has little or no relation to rays. During this year D and H decreased more times than increasing, but in former years the number

[1] Published by permission of the Director of the United States Coast and Geodetic Survey.

[2] For a previous report see *Terr. Mag.*, v. 30, 1925 (150-151).

of times these elements increased during rays was about the same as the number of times the elements were decreasing.

Effect of aurora on radio reception—Aurora was reported 58 times as follows: 34 faint, 21 bright, and 3 brilliant. On the 34 times that faint aurora was reported radio reception was poor 9 times, fair 10 times, and good 15 times. On the 21 times that bright aurora was reported radio reception was none one time, poor 2 times, fair 6 times, and good 12 times. Three brilliant auroras occurred, and at those times reception was poor, fair, and good once each. The observations for this year seem to indicate that good reception is very much more apt to occur than poor reception during a bright or faint aurora. In former years the results show that during a faint or bright aurora there was difficulty in radio reception about the same number of times as there were no difficulties. In former years the results were based on reports of cable and radio combined, while this year only reports of radio were considered. These results show that aurora causes poor reception in cable-transmission, while in radio reception no difficulties are experienced in the majority of cases.

Effect of the aurora on magnetic conditions—Of the 34 times that faint aurora was reported the magnetic characters were 17 (0) and 17 (1). Of the 21 times that bright aurora was reported there were 10 (0)-days, 8 (1)-days, and 3 (2)-days. The three brilliant auroras occurred on (1)-days in all cases. These results indicate that faint auroras occur on (0)-days about as often as on (1)-days and that bright auroras occur about the same number of times on (0)-days as on (1 and 2)-days, but that brilliant auroras occur on magnetically-disturbed days.

Relation between the Earth's magnetic field and radio reception—As summarized last year the record has been divided into night-broadcast reception, daytime long-wave reception, and night long-wave reception. There were 901 observations made during the past year, and the following table shows each group arranged according to reception and magnetic conditions.

Reception	None			Poor			Fair			Good		
Mag'c char.	0	1	2	0	1	2	0	1	2	0	1	2
Broadcast	30	27	3	68	32	1	103	49	1	126	39	2
Long-wave (daytime)	15	11	1	14	8	0	72	25	1	34	16	2
Long-wave (nightime)	1	1	0	18	19	3	55	24	0	71	28	1
Totals.......	46	39	4	100	59	4	230	98	2	231	83	5

A study of the above table shows that for broadcast reception when no reception occurs, the chances are that the Earth's magnetic

field is normal about half of the time, and that when reception is registered the ratio of magnetically-disturbed days is almost the same for any kind of reception. For long-wave night-reception the same ratio holds for fair and good reception, but for poor reception the chances are a little greater for a magnetically-disturbed day than for a normal day. The same ratios hold for the daytime long-wave reception with a greater proportion of no-reception days than for night-reception. In general the condition of the Earth's magnetic field is no index of the way radio reception is received.

Auroral frequency—The reports from Fort Yukon indicated the clear nights only from September 1 to November 5, inclusive. There were 29 clear nights in the interval and aurora was reported 8 times. At Sitka, between September 1, 1927, and May 15, 1928, there were 93 clear or partly cloudy nights, and aurora was recorded 15 times. Of the 78 times that no aurora was noted there were 68 (0)-days and 10 (1)-days. Of the 15 auroras noted there was only one bright aurora, and most of the others were pale glows, with the aurora apparently below the horizon. The one bright aurora occurred on a (2)-day and the 14 faint auroras and glows all occurred on a (1)-day. Reports of auroras in former years from various stations throughout Alaska showed that faint auroras occurred about half of the time on (0)-days and that bright or brilliant auroras occurred usually on magnetically-disturbed days. For Sitka the observations during the past year show that any aurora, irrespective of its brightness, occurs on a magnetically-disturbed day, and that there were magnetically-disturbed days of character (1) on which no aurora occurred.

Sitka Magnetic Observatory,
Sitka, Alaska

REVIEWS AND ABSTRACTS

(See also pages 158 and 172)

Price, A. T., and Chapman, S.: *On line-integrals of the diurnal magnetic variations.* London, Proc. R. Soc., A., vol. 119, 1928, pp. 182-196.

In place of taking the line-integrals of the horizontal component of the Earth's field around a closed circuit, as has been done in many investigations, the authors have taken the line-integral of the variations of the horizontal component. As the variations are practically always available from the records of fixed observatories and also with a high degree of precision, this method, which apparently only now has been tried out for the first time, appears to be promising. The principal objection to it is its limited application, Europe being the only region at present where observatories are located sufficiently close together.

The circuit investigated comprised the observatories Greenwich, Eskdalemuir, Rude Skov, De Bilt, and Stonyhurst, and encloses an area extending about 200 miles from north to south by about 500 miles east to west.

The data used were the hourly variations in horizontal intensity and declination or in the north and west components for the 20 international quiet days from May to August in the year 1924, which was one of low sunspot-number.

The effect of errors in the data and errors of interpolating along the circuit are considered. The conclusion reached is that the evidence for the existence of a potential for the diurnal magnetic variations is adequate, and that if any part does not possess a potential it must be but a small fraction. W. J. Peters

NOTE ON A VERTICAL-INTENSITY VARIOMETER

It is well known that the vertical-intensity (Z) variometer is considered the most unsatisfactory variation-instrument of the magnetic observatory, and although various types have been proposed, there is as yet no really good design. However, the possibility is not precluded that the old Lloyd's balance, in a somewhat altered form, may give good results, as the following data show.

In the magnetic observatory in Rude Skov (literally, Rude Forest) at Copenhagen there has been used for some time a small Z-variometer, the most conspicuous feature of which is the lightness of its moving parts, the needle, together with suspension, mirror, etc., weighing only about five grams. Because of the small weight, it has been possible to make the point of the pivots very fine. Following a suggestion by D. la Cour, the apparatus was mounted in an air-tight bell-glass from which the greater part of the air was removed. The variometer was made by the instrument-maker M. Laessöe-Müller of Copenhagen.

During twenty weeks the instrument worked well; the optical system was then disturbed, unfortunately, by a drop of oil falling on the prism, which interrupted the readings. Table 1 gives the determinations, from observations by M. J. Egedal, of the base-line values during the period while the variometer, designated VZ, was undisturbed. Reductions for values of intensity follow from the formula:

$$Z = VZ_0 + 6.5\ (200 - VZ) + 9.2t$$

TABLE 1—*Base-line determinations for vertical-intensity variometer, VZ, at Rude Skov*

Date	Incl'n	Hor. int.	Vert. int.	6.5 (200-VZ)	$9.2t$	ΔVZ	Base-line VZ_0
1927	° ′	γ	γ	γ	γ	γ	γ
Dec. 13	69 10.75	16987	44669	−11	− 4	−15	44684
24	12.4	64	73	−20.5	+11	− 9.5	82.5
30	13.1	56	80.5	+45.5	−49.5	− 4	84.5
1928							
Jan. 2	13.9	42.5	75	+12	−20	− 8	83
10	12.45	64	75.5	−24	+ 9	−15	90.5
31	12.4	66	79	−11	− 0.5	−11.5	90.5
Feb. 7	12.5	60	67	−15	− 0.5	−15.5	82.5
14	13.5	55	93	− 5	+ 6.5	+ 1.5	91.5
20	12.4	63	70.5	−28.5	+13	−15.5	86
28	12.8	56	68	−15	+ 2	−13	81
Mar. 6	12.65	57	65	− 9	− 5.5	−14.5	79.5
8	13.65	38	54	−30	+ 4	−26	80
13	13.65	47	78	+40	−48	− 8	86
23	14.15	34	63	−58	+27	−29	92
27	13.5	44	63	−49	+20	−29	92
Apr. 3	15.3	15	57.5	−68	+38.5	−29.5	87
12	12.1	66	67	−67	+55	−12	79
17	15.1	16	52.5	−39	+ 4.5	−34.5	87
23	69 12.2	16963.5	44664.5	−85	+67	−18	44682.5

From a plot of these determinations it will be seen that a mean value of 44685 gammas may be taken as a fair adjustment of the observed base-line values, and that the base-line value may safely be assumed to have remained constant. The advantage of this good performance of the instrument is that an upper limit for the error in the absolute determination can be found without the use of any hypothesis. Ordinarily the plot of base-line values is a curve, and it is necessary to make an adjustment; making an adjustment when the mean error of the observations is not known, however, is like solving the problem of one equation with two unknowns.

The mean difference between the observed values in the Table and the mean value is ± 4.3 gammas. This includes the errors due to possible non-constancy of base-line value and those involved in absolute determinations; thus the mean difference, ± 4.3 gammas, is an upper limit for the mean error in the absolute determinations. It will be seen from the Table that errors in absolute determinations may arise from many different sources; thus an error of $0.'1$ in inclination corresponds to an error of 3.8 gammas in the resulting base-line value. Since there are reasons for supposing the mean error in the determination of inclination at Rude Skov is about $\pm 0.'1$, it will be seen that the upper limit found in the simple manner mentioned yields valuable information.

Because of the difficulties generally experienced in the determination of the vertical component, any information regarding similar instrument-performances would be of value.

V. H. RYD

DET DANSKE METEOROLOGISKE INSTITUT,
COPENHAGEN, DENMARK

After seeing the above note, H. E. McComb, of the United States Coast and Geodetic Survey, writes: "It is interesting to note the success with which V. H. Ryd has operated a vertical-intensity variometer equipped with a very light magnet-system, particularly as experiments recently conducted by the U. S. Coast and Geodetic Survey with vertical-intensity variometers of the Schulze type indicated that one of the sources of instability is the type of pivots used. The magnet-system described by Mr. Ryd has a mass of about 5 grams, while those of the Schulze type have a mass of about 20 grams. In commenting upon the use of the Company's pivots with a magnet-system weighing 20 grams, it was stated by the General Electric Company that the application of this 20-gram load to their very sharp pivots was equivalent to a load of approximately 3,000 kilograms per square centimeter.

"It would be of further interest to know more of the details of the installation in vacuum, with special reference to the method used in cementing the window to the bell-jar, method of producing and maintaining a vacuum, extent of leakage, method of determination of sensitivity, etc."

REMARKABLE AURORAL DISPLAY OF JULY 7 TO 8, 1928

A number of communications giving details of the remarkable auroral display on the night of July 7–8, 1928, have been received. Among these is a summary with 20 reports from Dr. Willard J. Fisher of Harvard College Observatory, covering an area extending from Maine to Texas and from Michigan to 100 miles east of Boston, Massachusetts. The east-west extension is thus seen to be very great, although the aurora is not limited by the reports in that direction. At sea north of Cape Charles Light there was seen a broad arch of light from northwest to northeast, about three degrees wide, with its center about five degrees under the North Star. The streamers above reached about 80 degrees altitude in the northern half of the sky, so that the display at this point was wholly in the north at 20^h 30^m eastern standard time. About this same time, at Silver Lake Postoffice, New Hampshire, the sky was dark in the south up to a bright arch, well defined, with a maximum altitude of 12 degrees nearly due south. This bright arch over dark sky, with vertex about 15 degrees high due south, was also noted at Chebeague Island, Maine, from 22^h 00^m to 23^h 30^m. On the U. S. Coast Guard destroyer *Wainwright*, about 100 miles east of Boston, after the fog had broken away about 2^h 30^m, July 8, the streamers were observed to extend in the south to within 15 or 20 degrees of the horizon. Similar reports were received from Lansing, Michigan, and Malden, Massachusetts.

David I. Mondell reports that the light-intensity at Cambridge, Massachusetts, changed quickly in both horizontal and vertical directions, but never excepting the corona did it change along a diagonal axis. Two hues predominated, namely, coppery red and a pale grayish-blue, sometimes with a tinge of green. At times large portions of the southern sky would glow with a coppery-red color which faded rather slowly once it had appeared. About midnight violent changes of form were observed in and around the corona which assumed the appearance of a disturbed whirlpool; wisps, cones, curves, and angles of brightness suddenly appearing and as suddenly disappearing, replaced one another with great confusion and disorder.

The Bulletin of the American Meteorological Society states that at Worcester, Massachusetts, the southern limit of the display was at times barely visible above the horizon in the south, and that six or more distinct arches were visible at once, while the auroral corona was continually forming and disappearing. The depth and brilliance of the red and green areas were very impressive. At Little Rock, Arkansas, the display was seen in the north all night. At sea the aurora was reported to have been visible before the Sun set.

Second Officer E. Macaughey, of the Panaman steamer *Managui*, reports observing, on July 8, from 2^h 00^m until dawn, in latitude 39° 25′ north and longitude 73° 40′ west, a brilliant display. The streamers reached from the horizon to the zenith

with ripples of light passing through the entire display. The weather was fine and clear except for a small cloud bank near the northern horizon. There was very little static noticeable, radio reception was very good, and distance was not interfered with.

H. D. Harradon

Department of Terrestrial Magnetism,
Carnegie Institution of Washington,
August 18, 1928

AURORA AND LOW-FREQUENCY RADIO RECEPTION, JULY 7 TO 8, 1928

The aurora observed at Newton Centre, Massachusetts, began at $20^h\ 15^m$ Eastern Standard Time, July 7 as a bright arch in the northeast. An hour later an auroral crown developed near the zenith, with descending rays which at one time nearly filled the hemisphere, and which were at times strongly colored with pink and yellow-green. Broadcast reception from *WGY* at Schenectady, and *KDKA* at Pittsburgh, was greatly depressed during the entire evening, and did not rise appreciably above its normal low daytime-level. Although the Harvard Astronomical Laboratory at Cambridge has not yet reduced its record of *WBBM* for this period, Dr. Stetson reports very low field-values. My own record of field-strength from station *WCI* at Tuckerton, New Jersey, operating at 18 kilocycles, shows a striking change from the normal diurnal-curve for the past month, which had peaks at or near sunrise and sunset, with low field during the night. July 7 the sunset-peak was absent, with high values during the greater part of the night, and instead of a peak at sunset a deep depression appears in the early morning record of July 8, and a low and irregular field during the day. As there has been nothing like this in the previous daily records of this station, it is assumed that the change is associated with the aurora.

Greenleaf W. Pickard

Newton Centre, Mass.,
July 8, 1928

REPORT ON MAGNETIC STORM OF JULY 7 AND 8, 1928, AS RECORDED AT THE APIA OBSERVATORY

(*Latitude*, 13° 48′.4 *S.; longitude*, 171° 46′, *or* $11^h\ 27^m.1$ *W. of Gr.*)

The horizontal-intensity record showed a change from quiet conditions to a state of oscillation at $23^h\ 15^m$, July 7, but the deflection which may be regarded as the real commencement of the storm, was at $23^h\ 27^m$. The first movement of an increase of 35 gammas was followed by another four minutes later, bringing the intensity 50 gammas above the value of the starting point. At $23^h\ 42^m$ there was a rapid fall of 140 gammas in about six minutes, this being also the time of the first conspicuous movement in

declination, which moved 2 minutes westward practically instantaneously. The total range in horizontal intensity was 540 gammas, the value being 35315 on July 8 at 1^h 17^m and 34775 gammas at 9^h 20^m. The range in declination was 12 minutes, with a minimum at 0^h 30^m and a maximum at 4^h 20^m, the absolute values being approximately 10° 23′ east and 10° 35′ east. The reserve intensity-trace was recording most of the time between 8^h and 10^h, and moved in steps of 8 or 10 gammas in intervals of two minutes, more or less. While the observer was attending the instrument from 9^h 45^m to 10^h there was an increase of 120 gammas in about 15 minutes. The degree of disturbance became less noticeable after 11^h, but July 9 and 10 were both days of character 2.

ANDREW THOMSON, *Director*
C. J. WESTLAND, *Observer*

REPORT ON MAGNETIC STORM OF JULY 7 AND 8, 1928, AS RECORDED AT THE CHELTENHAM MAGNETIC OBSERVATORY AND ON ACCOMPANYING AURORA OBSERVED AT BRANDYWINE, MARYLAND[1]

(*Latitude* 38° 44.′0 *N.; longitude* 76° 50.′5 *or* 5^h 07^m.4 *W. of Gr.*)

A magnetic storm of the first magnitude, characterized by a sudden beginning, great intensity, and short duration, began at 23^h 30^m G. M. T., July 7, and continued until 11^h 00^m G. M. T., July 8. The ranges were: Declination, 4° 00′; horizontal intensity, 1270+ gammas; vertical intensity, 642+ gammas, perhaps two or three times as great. The maximum value of declination, 10° 00′.6, was at 5^h 48^m July 8, and the minimum, 6° 00′.4, at 6^h 34^m on the same day. The maximum value of horizontal intensity was 19119 gammas at 1^h 10^m July 8, with a minimum value of less than 17849 gammas, at which point the record went off sheet. In vertical intensity the maximum value recorded was 54932 gammas at 2^h 02^m July 8, with a minimum value of less than 54290, when the record went off sheet. The storm was accompanied by a fine display of aurora and serious interference with telegraph and telephone transmission.

The aurora as observed by S. G. Townshend, Jr., Magnetic Observer, at Brandywine, Maryland, began at 1^h 30^m G. M. T., July 8, as a single narrow shaft of light. At 2^h 30^m there was a beautifully colored sky along the horizon and a shaft of light emanated from the horizon and gradually progressed toward the west, gradually increasing in intensity and height until it extended to the zenith. It intensified and faded from time to time until 5^h 00^m July 8, when the colorful rays formed a beautiful dome-like appearance at 70° from the south horizon. At intervals bright parallel streaks of light were seen interspersed with a colorful sky.

GEO. HARTNELL, *Observer-in-Charge*

[1]Communicated by E. Lester Jones, Director, United States Coast and Geodetic Survey.

PRINCIPAL MAGNETIC STORMS RECORDED AT THE WATHEROO MAGNETIC OBSERVATORY, APRIL TO MAY, 1928

(*Latitude* 30° 19′.1 *S.; longitude* 115° 52′.6 *or* 7^h 44^m *E. of Gr.*)

May 27-29, 1928—The storm of May 27 to 29 was prolonged but of mild severity and characterized by long-period oscillations. The storm began May 27 at 13^h 28^m in declination and vertical intensity and at 13^h 26^m in horizontal intensity, and ended May 29 at 20^h 17^m, the ranges being as follows: Declination, 22′.2; horizontal intensity, 179 gammas; vertical intensity, 172 gammas. The preliminary comparatively quiet period lasted until 3^h on May 28, when the greatest changes in the elements began. These were steady and progressive during the second period, which lasted until 8^h. The third period of 16 hours was characterized by long-period oscillations of moderate amplitude. The fourth period began at 0^h on May 29, during which there was a gradual recovery to normal values.

H. F. JOHNSTON, *Observer-in-Charge*

PRINCIPAL MAGNETIC STORMS RECORDED AT THE SITKA MAGNETIC OBSERVATORY, APRIL TO JUNE, 1928[1]

(*Latitude* 57° 03′.0 *N.; longitude* 135° 20′.1 *or* 9^h $01^m.3$ *W. of Gr.*)

Greenwich Mean Time						Range		
Beginning			Ending			Decl'n	Hor. int.	Vert. int.
1928	*h*	*m*	*d*	*h*	*m*	′	γ	γ
May 10	12	15	13	12	..	47.7	433	596
May 27	14	47	29	24	..	144.3	1328**	787*
June 12	5	00	12	20	..	77.7	457	616*
June 13	7	16	13	20	..	189.5	846*	550*
June 22	8	00	23	5	..	71.4	800	537

*Curve went off the paper in one direction. **Curve went off the paper in both directions.

HAROLD A. COTTON, *H. & G. Engineer-in-Charge*

[1]Communicated by E. Lester Jones, Director, United States Coast and Geodetic Survey.

PRINCIPAL MAGNETIC STORMS RECORDED AT THE HUANCAYO MAGNETIC OBSERVATORY, MAY TO JULY, 1928

(*Latitude* 12° 02′.7 *S.; longitude* 75° 20′.4 *or* $5^h\ 01^m.4$ *W. of Gr.*)

Greenwich Mean Time							Range		
Beginning			Ending				Decl'n	Hor. int.	Vert. int.
1928	*h*	*m*	*d*	*h*	*m*		′	γ	γ
May 10	12	14	12	17	20		6.8	373	29
May 27	13	25	29	17	45		11.0	540	55
July 7	23	16	8	20	32		24.2	863	56

May 10–12, 1928—This prolonged magnetic disturbance, hardly severe enough to class as a storm, began suddenly in all three elements, the horizontal intensity increasing 71 gammas in six minutes. There were periods of quiet during the three days of disturbance, but the horizontal intensity was subnormal during the whole period, and the fluctuations were marked during the daily maximum.

May 27–29, 1928—This magnetic storm of moderate intensity began suddenly with an increase in horizontal intensity of 78 gammas in seven minutes; the vertical intensity and declination were also affected but less sharply. The horizontal-intensity record showed a serrated appearance until approximately $21^h\ 30^m$, and then during the balance of the storm moderate peaks and bays, usually not more than one per hour. No large or rapid fluctuations were recorded, but the horizontal intensity was abnormally low during the whole storm.

July 7–8, 1928—This violent magnetic storm began suddenly in all elements, increasing 295 gammas in horizontal intensity during the first twelve minutes and decreasing 190 gammas during the following nine minutes. For the first six hours of the storm the horizontal-intensity record was so badly disturbed that it is impossible to follow it accurately, while declination and vertical intensity were greatly disturbed, making, for this observatory, rapid and large changes. During this period the measured large and rapid changes in horizontal intensity gave an average of 31 gammas per minute. After 11^h on July 8 the elements were relatively less disturbed, with only one rapid increase in horizontal intensity of 210 gammas in seven minutes at $15^h\ 35^m$. The storm ended rather abruptly on July 8, but was followed by subnormal intensities for a few days.

All times given are Greenwich civil mean time.

PAUL G. LEDIG. *Observer-in-Charge*

REVIEWS AND ABSTRACTS

(See also pages 158 and 164)

Stagg, J. M.: *The time-interval between magnetic disturbance and associated sunspot-changes.* London, Met. Office, Geophys. Mem., No. 42, 1928, 16 pp. 31 cm.

This is a statistical investigation based, for the first part, on the selection for each month of five days of greatest international magnetic character-number, and tabulating for the corresponding six days before and the one day after, the difference in the sunspot-areas from day to day. The object of this change over previous procedure in similar investigations was to discover whether there might not be a more intimate relation between the times of appearance or disappearance of sunspots and the times of subsequent associated magnetic storms than between the times of these storms and the days on which the area of sunspots might be at a stationary maximum or minimum. The data for 35 years, 1890–1924, were used. There appears to be a well-marked tendency for the increase of sunspot-area from the fifth to the fourth day before the magnetic disturbance to exceed the increase on any other day of the group of seven days selected around the time of disturbance.

Since the arbitrary selection of five days for each month must necessarily include some days of no great magnetic disturbance, another part of the investigation is based on the selection of 366 days of international figure not less than 1.5. The result practically confirms the conclusions for the five days per month.

Both positive variability, increase in area of spots, and negative, or decrease are considered. The analysis was also applied to 355 quiet days of magnetic character-figure 0.0 in the 20 years, 1906–1925.

It is the author's opinion that the better measure of the time of passage of the electrical particles from the Sun to Earth is the interval between the day of change of sunspot-area and the subsequently disturbed or quiet conditions, rather than the interval between a stationary condition of maximum or minimum of sunspot-area and the terrestrial-magnetic condition associated with it.

W. J. Peters

Watson, R. A.: *Electric Potential-Gradient Measurements at Eskdalemuir,* 1913–1923. London, Met. Office, Geophys. Mem., No. 38, 1928, 16 pages.

The paper summarizes and discusses the electric potential-gradient measurements at Eskdalemuir during 1913 to 1923, recorded continuously by means of a Kelvin water-dropper connected to a Dolezalek electrometer. Part I describes briefly the apparatus and its environment. "No material change has been made in the arrangement of the instrument or in its surroundings during the period considered, and the annual change due to the growth of vegetation on the bare moorland surroundings is slight." The absolute observations for the reduction-factor, made several times each month on a level lawn some 20 or 30 yards from the jet, the methods used, and some of the more important special reduction-factor control-observations are then discussed.

The theory and constants of the instrument are given and its behavior under certain specified conditions is determined from the numerical values obtained. In favorable cases it was possible to detect and measure approximately the

potential changes on the electrograms caused by 186 isolated lightning-flashes occurring on 33 days during otherwise calm periods; for 135 cases the potential was increased by the flash (positive discharge), and for 51 cases the potential was decreased (negative discharge), the ratio of positive to negative discharges being about the same as found by Wilson at Cambridge.

For the discussion in part II of potential gradient on quiet days only days of electrical character "0*a*" are considered, "0" denoting that the potential did not become negative at any time during the day, and "*a*" that in no hour was there a range of 1,000 volts per meter. The total number of such days and the resulting average monthly values for the eleven-year period were as follows:

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Total 0*a* days 1913-1923............	81	88	85	98	111	124	107	103	112	108	87	75
Average potential gradient in volts per meter.........	321	337	280	241	209	181	195	207	232	263	335	322

Apart from several irregularities, the annual variation indicated is a simple one, with a minimum at midsummer and a maximum at midwinter, the ratio of the extreme values being 1.8.

The yearly mean potential-gradient values for 0*a* days only for 1913-1923 are 252, 237, 266, 248, 287, 282, 248, 262, 249, 257, and 278, respectively, with an eleven-year mean of 260. They start with sunspot-minimum and show a peak in the potential gradient about the middle of the period. However, since the yearly means for the latter years of the sunspot-cycle rose at Eskdalemuir in spite of a decrease of the sunspot-number, the author believes that the effect of adding these latter years will be to greatly reduce the correlation-coefficient, +0.90, which Bauer found in his analysis of the Eskdalemuir data for 1912 to 1919.

The average monthly diurnal-variation curves, based on all 0*a* days obtained from 1913 to 1923, of the potential gradient are given for each month of the year. The non-cyclic corrections applied in the ordinary way to make the values at 0^h and 24^h equal varied greatly in magnitude and sign in the individual months, and "it cannot be stated with confidence that 0*a* days tend to be days either of rising or falling potential." Harmonic analyses of the average monthly and seasonal diurnal-variation curves have been made. The results for the entire eleven-year period and also for the two groups 1913-1918 and 1919-1923, respectively, show it unwise to give too much weight to small variations, even for the eleven-year series. The values for the six-hour and eight-hour terms "are to be viewed with suspicion," since "they are very irregular both in amplitude and in phase-angle."

Confirming data from the majority of other stations, the phase-angle of the twelve-hour wave appears almost constant throughout the year. Of meteorological effects observed at Eskdalemuir and at Kew, "it appears that the larger the diurnal variation of those factors which assist or retard the stirring up of the lower layers of the atmosphere, the larger is the twelve-hour term."

The twenty-four-hour terms at Kew and Eskdalemuir have some points of

resemblance, but also some striking dissimilarities. These are: (*a*) The amplitude decreases in both cases fairly regularly from winter to summer, but is very much more marked at Kew; (*b*) the phase-angle decreases from winter to summer, the time of maximum being retarded from about 17^h to about midnight, and the variation is somewhat greater at Kew; (*c*) the amplitude is considerably greater at Eskdalemuir for all seasons than at Kew, and is always greater than that of the twelve-hour term, while at Kew the twenty-four-hour term equals the twelve-hour term in winter, and is very much less in summer.

The results of investigation of relations between wind-speeds and potential gradients at Eskdalemuir are given in Part III. Among the important conclusions, "it appears . . . safe to assert that it is the wind-speed or the associated turbulence which has so marked an effect on the potential gradient, but it is probable that some temperature-effect also exists."

The production and probable effects of certain local atmospheric-electric charges on the variations of the potential gradient are treated from the standpoint of recent advances in meteorology and atmospheric electricity. The main conclusions reached are stated by the author as follows: "Summarizing, we believe that the annual and diurnal variations of potential gradient are controlled by two factors depending on universal time and one depending on local time. Over land the latter in general masks the former and differs from place to place. Over the sea the universal-time factors are the important ones." The desirability of additional diurnal-variation data at sea is emphasized.[1]

S. J. MAUCHLY

SCHMID, FRIEDRICH: *Das Zodiakallicht, sein Wesen, seine kosmische oder tellurische Stellung*. Hamburg, Verlag von Henri Grand, 1928 (x+132 mit einem mehrfarbigen Titelbilde, 22 Abbildungen im Text, 3 Tafeln und 3 Tabellen). 23 cm.

Among the few celestial phenomena which may be studied without the use of instruments and in the observation of which the purely visual method with the unaided eye is likely to play the principal rôle for some time to come, may be classed the zodiacal light and the attendant counterglow (Gegenschein). Yet, notwithstanding its mysterious beauty and the ease with which it may be observed, even in the temperate zones, we find, as a rule, surprisingly meager information regarding the zodiacal light, either of descriptive or theoretical nature, in text-books on astronomy, and although many theories have been propounded to account for its origin, no universally accepted explanation has yet been advanced.

Students of astronomy and geophysics will, therefore, welcome this recent treatise, which is entirely devoted to the consideration of the zodiacal light and allied phenomena. It is based primarily on the author's own unique series of observations and studies extending over a period of thirty-six years. Although these observations relate to a single locality in Switzerland (latitude 47° 21′ north), such records as were available for other regions of the Earth have been utilized. The paucity and fragmentary character of these, however, emphasize the need of obtaining, for the ultimate elucidation of the problem, additional extended data, particularly in the Southern Hemisphere.

The principal topics discussed by the author are: The visibility of the zo-

[1]Such data are now being obtained aboard the *Carnegie* on her Cruise VII (see this JOURNAL, v. 33, Mar. 1928, pp. 1-10).—*Ed.*

diacal light, methods of observation, its nature and position, the dimensions and form of the Earth's atmosphere, the zodiacal light as an atmospheric-optical phenomenon and its nightly and annual movements, the "Earth-light," Gegenschein, and "Lichtbrücke" (luminous band connecting the zodiacal light and Gegenschein), the effect of atmospheric absorption on the zodiacal light and its parallax, and the position of its plane.

The chief interest centers about the theory, previously published by the author in various journals, to account for the cause and nature of the zodiacal light. He holds that it is due to sunlight reflected from the lenticular extension of the Earth's atmosphere which, under the influence of the Earth's rotation, is greatly expanded at the equator and flattened at the poles. The objection which immediately presents itself, namely, that the phenomenon follows the plane of ecliptic rather than that of the equator is met by the assertion that the tenuous atmospheric protuberance is displaced by the gravitational force exerted by the Sun and the other planets, all of which lie near the plane of the ecliptic. According to this conception, the phenomenon belongs rather to meteorological optics than to astronomy. The theory is not in agreement with the explanation admitted by the majority of astronomers, who attribute the zodiacal light to reflected sunlight from innumerable small bodies, possibly dust or other fragments, existing in a lens-shaped region surrounding the Sun, having its greatest diameter nearly in the plane of the ecliptic and extending beyond the orbit of the Earth, to which cosmical theory the author offers several objections.

H. D. Harradon

Jakosky, J. J.: *Fundamental factors underlying electrical methods of geophysical prospecting, with special reference to the inductive processes.* Engineering and Mining Journal, New York, Feb. 11 and 18, 1928, 16 pp.

The author confines his discussion to a brief consideration of the fundamental factors underlying the operation of electrical methods for geophysical prospecting and geological subsurface investigations. It is pointed out that electrical methods can be advantageously employed when the electrical conductivities of the different strata or components of the Earth's surface differ considerably and that the greater the difference in electrical conductivity between the mineralized area and the surrounding envelope (earth), the more pronounced is the effect upon the recording or detecting instruments. Generally speaking, it is necessary that the difference in conductivity be of the order of 1 to 100 or more, and electrical prospecting methods are of value only in locating mineralized areas. Unless the geology and manner of ore-occurrence of a district are well known, it is difficult to obtain an authoritative idea of the commercial values of the mineralized areas. The paper treats, in a general way, of: (*a*) Factors determining effective conductivity, (*b*) frequency-effects, and (*c*) current-distribution, including "skin-effect."

Under the types of electrical geophysical methods the author first discusses: Applied-potential systems (direct or alternating current), self-potential systems, and the contact-method. The different kinds of electrodes available for the best results by these methods are also described. By far the greater part of the paper is devoted to the main fundamentals underlying the operation of the electromagnetic or inductive methods of prospecting. The inductive method is so named because the current flowing in the underground conductor is obtained

by electromagnetic induction instead of by use of ground-electrodes, as in the applied-potential systems or by direct contact with the ore-body. Space will not permit a detailed review of the author's treatment of this subject, and it must suffice to say that his development of the principles involved and his descriptions of instruments and methods are adequate for the information and use of readers interested in prospecting and familiar with the principles of electromagnetic induction. Besides numerous diagrams and several illustrations of instruments, there are two interesting tables entitled "Resistance and conductivity of certain typical strata to electric current" and "Results obtained by diamond drilling on certain 'indications,'" respectively.

In concluding, the author states that "it would be futile at this stage of development of the art of geophysics to attempt to define arbitrarily the field of application for each of the various processes. . . . Generally speaking, it can be said that the inductive process is not applicable unless mineralized areas are present which have a conductivity considerably greater than the surrounding earth. My experience leads me to believe that the applied-potential processes, generally speaking, are of more value in tectonic and geological investigations, and that the inductive methods are of greater value in general mining and exploration work."

S. J. MAUCHLY

BENCKER, H.: *The determination of the magnetic moment of liquid compasses.* Hydrogr. Rev., Monaco, vol. 5, No. 1, May, 1928, pp. 181-201.

But little attention is usually given to specifications in the purchasing of compasses for the merchant service, the yachting world, and for expeditions both by land and sea. No specifications can be considered complete that do not assign limits for the magnetic moment. The methods given in text-books for bar-magnets are not suitable for compasses from which the magnet or system of magnets is not readily removable. Lieutenant Commander Bencker's article is especially opportune. He gives first a brief résumé of papers on the same subject that have appeared from time to time in the *Annalen der Hydrographie und Maritimen Meteorologie*, and then describes the method which has been employed in the French Hydrographic Office. This consists of three distinct operations: (*a*) Measuring the terrestrial field where the experiment is to be made; (*b*) measuring the magnetic moment of a magnetized bar to be used later as a standard of comparison; and (*c*) measuring the moment of the compass by oscillation-observations with a small auxiliary compass. Operations (*a*) and (*b*) may be performed immediately before and after (*c*) if the highest precision is required, or they may be made at long intervals if many compasses are to be examined and no great precision required.

The essential feature of the method lies in operation (*c*). The periods of the auxiliary compass are observed at various distances directly over the center of the bar-magnet when this is lying in the magnetic meridian, with north-seeking end north, the magnetic moment having been determined under (*b*). In a similar manner the periods are determined at various distances over the compass the magnetic moment of which is sought. The auxiliary compass is placed upon wooden cylinders of about the diameter of the auxiliary. They are accurately turned and are of various lengths, which will give any desired height by superimposing them over the center of the bar-magnet or over the center of the compass the moment of which is sought. From the times of oscillations and the differences between distances, the height of the auxiliary compass above the magnets inclosed in the bowl may be computed. Samples of observations and computations are given in detail, and many figures are used in illustration.

W. J. PETERS

NOTES

22. *German Geophysical Society*—The seventh meeting of the Deutsche Geophysikalische Gesellschaft will be held, in conjunction with the Section for Geophysics of the 90th assembly of the Gesellschaft Deutscher Naturforscher und Aerzte, September 19 to 21, 1928, in Hamburg. Among papers to be presented are: *Schmidt, Ad.*, Referat über den Stand der erdmagnetischen Forschung; *Reich*, Lokale und regionale magnetische Anomalien in Schleswig-Holstein; *Pollack*, Das Periodogramm der magnetischen Charakterzahlen; *Jung*, Beitrag zur Auswertung von Drehwagemessungen; *Wölcken*, Weitere Messungen der durchdringenden Höhenstrahlung.

23. *International Astronomical Union*—At the recent meeting of the International Astronomical Union, held at Leiden, Holland, Sir Frank Dyson, Astronomer Royal of England, was elected president for the next meeting, which is to be held in the United States in September 1932. This will permit visiting astronomers to be in the United States at the time of the total eclipse of the Sun, which will be visible in New England and eastern Canada on the afternoon of August 31, 1932.

24. *Fourth Pacific Science Congress, Java, 1929*—The Fourth Pacific Science Congress will be held at Batavia and Bandoeng, Java, May 16 to 25, 1929. These dates were chosen chiefly on account of the favorable climatic conditions in Java at that time and to afford those attending the Congress an opportunity of observing the total solar eclipse which will be visible in the vicinity of Penang on May 9. The Congress will be organized in divisions as follows: (*A*) Division of Physical Sciences; (*B*) Division of Biological Sciences; (*C*) Division of Agricultural Sciences. Abstracts of any papers to be presented should be sent in duplicate, to reach the First General Secretary of the Congress, Dr. H. J. Lam (Botanical Gardens, Buitenzorg, Java) by January 1, 1929, the complete papers to be sent as soon as possible thereafter. Following the opening session at Batavia, the scientific meetings are to be held at Bandoeng (about 2,300 feet altitude), on account of the cooler climate.

The provisional scientific program of the Division of Physical Sciences includes: (1) Natural and technical conditions controlling wireless telegraphic possibilities over the Pacific Ocean; (2) Outcome of modern methods for scientific vulcanological research (thermal, chemical, seismic, magnetic, and other methods); (3) results of gravity-determinations upon the Pacific Ocean and the organization of further research; (4) geophysical means and methods of mineral-prospecting (gravity, terrestrial-magnetic, radioactive, seismic and electric methods).

25. *New Geophysical Institute, Bergen*—On June 7, 1928, there was opened, at Bergen, Norway, a new and splendid Geophysical Institute, built by funds raised by local contributions. The new building of three stories and basement, with a tower for meteorological work, is built on a bluff commanding an extensive view over the fjord and islands.

The ground floor contains laboratories under the charge of Prof. Helland-Hansen, for investigating various branches of chemistry and geophysics, particularly studies of the wind-currents and water-currents from the dyanmical point of view.

On the next floor are the laboratories of Dr. H. U. Sverdrup and Dr. Krogness, the former interested chiefly in theoretical meteorology and the latter in terrestrial magnetism and cosmical physics. Dr. Krogness is about to compile magnetic observations from all parts of Norway and to undertake, for the first time, a general magnetic survey of the country. He will have the coöperation of Prof. C. Störmer, Prof. S. Saeland, and Prof. L. Vegard, all well known for their studies in geophysics, and of Dr. Th. Hesselberg, of Oslo. Dr. Sverdrup is discussing the important scientific observations made on the recent "Maud" expedition for a special publication of the Institute.

26. *New Magnetic Observatory at Niemegk*—The extension of the Berlin-Potsdam suburban electric-car system has so disturbed the magnetic registrations at the Potsdam Observatory as to invalidate them for scientific use, while proposed development near the auxiliary station at Seddin will, in the near future, also invalidate the registrations there. After a thorough preparatory reconnaissance, a new site, which is likely to remain free from such disturbances for some time to come, has been selected about 1.5 km west of the small town of Niemegk (geographic coördinates, 52° 04′ north latitude and $12° 41' = 50^m 12^s$ east longitude). It is hoped to complete the new observatory during the present year. Until observations are inaugurated at the new observatory, all registrations and absolute measurements heretofore made at Potsdam will be transferred to Seddin. That proper transition from the old to the new series may be assured, observations will be continued at Seddin for some time after starting the new series at Niemegk.

27. *Byrd Antarctic Expedition*—The first section of the expedition under the leadership of Commander R. E. Byrd left New York on the ship *City of New York* (formerly the *Samson*) August 20, 1928, for Dunedin, New Zealand (via the Panama Canal), and thence for Antarctica. It is planned to obtain not less than one year's continuous magnetic and atmospheric-electric records at a fixed observatory at the base-station (about 78° south latitude and 165° west longitude), as well as to make magnetic observations at stations during sledge-trips. Besides the sledge-trips to establish caches for Commander Byrd's flights, it is hoped that a trip may also be made to near the region of the south magnetic pole. The apparatus for the magnetic and atmospheric-electric work has been loaned by the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, where R. F. Shropshire and F. T. Davies of the Expedition's staff had special training for the program developed by the Department. McGill University of Montreal, the United States Naval Research Laboratory, and the United States Weather Bureau are also coöperating in the scientific work through the loan of atmospheric-electric, spectroscopic, and meteorological equipment.

28. *Cruise VII of the Carnegie*—According to wireless messages which are received from the *Carnegie*, the party is obtaining regularly complete magnetic, electric, oceanographic, and meteorological data in accordance with the program planned (see this Journal, v. 33, pp. 1-10). The new plankton-catcher, after Pettersson's model, taken on board at Hamburg, is operating successfully. Deep-sea temperatures and water-samples are being regularly secured, as well

as tow-net drags at the surface and at depths of 50 and 100 meters; for the station of August 11 temperatures and water-samples were obtained to a depth of 5,600 meters. Leaving Reykjavik July 27 with a fair wind, the vessel was 300 miles east of Cape Farewell July 29, and heading down toward Newfoundland, was 200 miles southwest of Cape Farewell on August 3. On August 8 the vessel was 1,100 miles east of Portland, Maine, and on August 10, 1,400 miles due east of Washington. The noon position August 13 was 36° 20′ north latitude and 45° 52′ west longitude. August 16, at 30° north latitude and 40° west longitude, head-winds made it advisable to follow the *Carnegie's* track of 1913 southeast to 20° north latitude, in the expectation of proceeding thence south for the proposed loop off the northeast coast of South America. The position August 18 was 28° 55′ north and 39° 30′ west, while on August 26 the vessel was 1,500 miles east of Barbados. The turn to the northwest towards Barbados was made at latitude 8° north and longitude 36° west August 31, when the calm was broken by storm and southwest winds; ten oceanographic stations to depths of 2,000 to 5,000 meters had then been obtained since leaving the Great Banks. The vessel arrived September 17, 1928, at Bridgetown, Barbados, British West Indies.

29. *Personalia*—Dr. *Julius Bartels*, Privatdozent at the University of Berlin, has been appointed Ausserordentlicher Professor of minerology and geology at the Forstliche Hochschule in Eberswalde.

Dr. *Ludwig Steiner* has been appointed director of the Hungarian Reichsanstalt für Meteorologie und Erdmagnetismus in Budapest.

The Bruce prize for the period 1926-1928 has been awarded by the Royal Society of Edinburgh, to Dr. *H. U. Sverdrup*, of the Geophysical Institute, Bergen, Norway, for his contributions to the knowledge of the meteorology, magnetism, and tides of the arctic regions.

Sr. Ing. *Joaquin Gallo*, director of the National Astronomical Observatory of Mexico, received the honorary degree of doctor of science at Northwestern University, June 18.

According to the Monthly Results of the Royal Alfred Observatory, Mauritius, for June, 1927, *R. A. Watson* has been appointed director of that observatory.

Dr. *Gregory Breit*, mathematical physicist of the Department of Terrestrial Magnetism, has been assigned to pursue his studies in atomic physics in various laboratories and universities of Europe for one year, beginning September 1, 1928. During his absence, Dr. *M. A. Tuve*, also of the Department of Terrestrial Magnetism, will carry on the high-potential and conducting-layer experimental work, with the assistance of Dr. *R. E. Gaviola* and *L. R. Hafstad*, who have been appointed associate physicist and assistant physicist, respectively, for one year.

It is with great regret that we announce the death on August 12, 1928, at the age of sixty-eight years, of Dr. *Charles Chree*, F.R.S., from 1893 to 1925 superintendent of the Kew Observatory. He also took an active part in the organization in 1919 of the Section of Terrestrial Magnetism and Electricity of the International Geodetic and Geophysical Union of which he was the first president, an office which he held until 1927. His numerous publications on terrestrial magnetism, atmospheric electricity, and allied subjects, in which field he was a leading authority, constitute important contributions to the knowledge of those sciences.

LIST OF RECENT PUBLICATIONS

By H. D. Harradon

A—Terrestrial and Cosmical Magnetism

Apia Observatory. Report for 1924. Wellington, W. A. G. Skinner, Govt. Printer, 1927, 84 pp. 25 cm.

Azores, Service Météorologique. Résumé d' observations de 1926. Lisbonne, Imprimerie Nationale, 1928, 23 pp. 32 x 24 cm. [Contains annual values of the magnetic elements and monthly mean values of declination at the S. Miguel Observatory for 1926.]

Bangkok, Royal Survey Department. Report on the operations of the Royal Survey Department, Ministry of War, for the year 1925-26. Bangkok, Daily Mail Press, 1927 (67 with maps and illus.). 34 cm. [Contains results of magnetic observations 1905-1926.]

Bencker, H. The determination of the magnetic moment of liquid compasses. Hydrogr. Rev., Monaco, v. 5, No. 1, May, 1928 (181-201 with 2 tables).

Chapman, S. The correlation of solar and terrestrial magnetic phenomena. Nature, London, v. 121, June 23, 1928 (989-991).

Chapman, S., and T. T. Whitehead. The influence of electromagnetic induction within the Earth upon terrestrial magnetic storms. Reprint: Proc. Internat. Math. Cong., Toronto, 1924 (313-337).

Egedal, J. Ueber eine Verbindung zwischen den mondentägigen und den sonnentägigen Variation der magnetis hen Deklination. Zs. Geophys., Braunschweig, Jahrg. 4, Heft 3, 1928 (155-158). [Korrektion zu einer früheren Mitteilung und eine Prüfung der aufgestellten Formel.]

Egypt, Physical Department. Meteorological report for the year 1922. Cairo, Ministry Pub. Works, Physical Dept., 1928 (xiii + 170). [Contains values of the magnetic elements at Helwan Observatory for 1922.]

Gibault, G. L'orientation du pigeon voyageur et les phénomènes magnétiques, électriques, et météorologiques. Nature, Paris, No. 2788, 1er juillet 1928 (17-19).

Greaves, W. M. H., and H. W. Newton. Large magnetic storms and large sunspots. London, Mon. Not. R. Astr. Soc., v. 88, May, 1928 (556-567). [The paper gives details of a comparison between large magnetic storms and large sunspots during the period April 1874, when systematic solar observations were started at Greenwich, to December 1927. As a result of this comparison of records extending over a period of more than fifty years, it was found that individual storms and individual spots are associated with each other more often than can be ascribed to mere chance. The tendency to association appears to be greater for the very largest storms of all. It would seem that whatever solar activity is responsible for a magnetic storm, it will probably manifest itself as a large sunspot. But attention is called to a case of a very large storm taking place at a time when only very moderate spots were visible. No very definite evidence was found of a tendency for these large storms to be followed by another magnetic disturbance after an interval of one solar rotation. The evidence available suggests a possible slight tendency for recurrence, but it is not very conclusive.]

Gunn, R. The diamagnetic layer of the Earth's atmosphere and its relation to the diurnal variation of terrestrial magnetism. Phys. Rev., Menasha, Wis., v. 32, July, 1928 (133-141).

KOENIGSBERGER, J. Zur Empfindlichkeitsbestimmung von magnetischen Variometern und zur Eichung der magnetischen Felder von Spulen. Zs. Geophys., Braunschweig, Jahrg. 4, Heft 3, 1928 (151-152).

LA COUR, D. Om et nyt apparat til jordmagnetiske maalinger. Fysisk Tidsskr., Kjöbenhavn, v. 25, No. 4/5, 1927 (105-114).

MATHIAS, E. Mesures magnétiques dans la Creuse, la Dordogne, et la Haute-Vienne. Paris, C.-R. Acad. sci., T. 186, No. 23, 1928 (1499-1501).

MAURAIN, CH., ET L. EBLÉ. Variation diurne de l'agitation magnétique au Val-Joyeux près Paris. Paris, C.-R. Acad. sci., T. 186, No. 24, 1928 (1641-1642).

MAURITIUS, ROYAL ALFRED OBSERVATORY. Results of magnetical and meteorological observations for the months of July to December, 1926 (new series, v. 12, pts. 7-12, pp. 107-215) and January to June, 1927 (new series, v. 13, pts. 1-6, pp. 1-105). Port Louis, Govt. Press, 1926, 1927. 34 cm.

Annual report on the Royal Alfred Observatory for the year 1926 (M. Olivier, Officer-in-Charge). Port Louis, Govt. Press, 1927, 3 pp. 34 cm. [Contains mean values of the magnetic elements for the year 1926.]

MILLIKAN, R. A., AND G. H. CAMERON. Evidence for the continuous creation of the common elements out of positive and negative electrons. Washington, D. C., Proc. Nation. Acad. Sci., v. 14, June, 1928 (445-450). Reprinted in Sci. Amer., New York, N. Y., v. 139, Aug., 1928 (136-137).

PARIS, INSTITUT DE PHYSIQUE DU GLOBE. Annales de l'Institut de Physique du Globe de l'Université de Paris et du Bureau Central de Magnétisme Terrestre. Publiées par les soins de Ch. Maurain. Tome VI. Paris, Les Presses Universitaires de France, 1928 (iv + 148 avec figs.). 31 cm. [This volume contains the following articles pertaining to terrestrial magnetism and atmospheric electricity: L. Eblé—Observations magnétiques faites à l'observatoire de Val-Joyeux pendant l'année 1926; E. Tabesse—Observations magnétiques faites à l'observatoire de Nantes pendant l'année 1926; J. MacLaughlin—Recherches sur les gros ions; Ch. Maurain—Mesures magnétiques en Alsace et en Lorraine; E. Tabesse—Mesures magnétiques dans le centre et l'Ouest de la France; Service Géographique de l'Armée—Mesures magnétiques au Maroc; Capitaine J. Nevière—Première contribution à l'étude du magnétisme terrestre en Haute-Volta; Variations des éléments magnétiques lors des principales perturbations magnétiques de l'année 1926 (graphiques).]

PRICE, A. T., AND S. CHAPMAN. On line-integrals of the diurnal magnetic variation. London, Proc. R. Soc., A, v. 119, No. 782, 1928 (182-196).

REICH, H. Magnetische Messungen in Aachener und Erkelenzer Steinkohlengebiet und ein Versuch ihrer geologischen Deutung. Jahrb. Geol. Landesanstalt 1926, Berlin, Bd. 47, Heft 1, 1926 (84-115 mit 3 Tafeln).

Die magnetischen Anomalien Norddeutschlands und ihre wahrscheinlichen geologischen Ursachen. Zs. D. Geol. Ges., Berlin, Bd. 79, Nr. 11/12, 1927 (325-339).

ROTHÉ, E., ET MME A. HÉE. Sur les propriétés magnétiques des zones stratigraphiques de la vallée du Rhin. Paris, C.-R. Acad. sci., T. 187, No. 1, 1928 (52-54).

SCHMIDT, AD. Ergebnisse der erdmagnetischen Beobachtungen in Potsdam im Jahre 1927. Met. Zs., Braunschweig, Bd. 45, Heft 6, 1928 (229-231).

SCHOSTAKOWITCH, W. B. Die Sonnenflecken. Periodicität in der Naturerscheinungen. Irkutsk, Verh. Mag. Met. Obs., No. 2-3, 1928 (1-80; 125-140). [The author discusses briefly the relationship between terrestrial magnetism and sunspots but the greater part of the article deals with the relationships of sunspots with other natural phenomena. Text is in Russian and German.]

Stagg, J. M. The time-interval between magnetic disturbance and associated sunspot-changes. London, Met. Office, Geophys. Mem., No. 42, 1928, 16 pp. 31 cm.

Tonta, L. Concerning the correction of the quadrantal error in compasses of large magnetic moments. Hydrogr. Rev., Monaco, v. 5, No. 1, May, 1928 (173-180).

New Zealand. Records of the Survey of New Zeland, volume IV. (Supplementary to annual report.) Annual reports of parties and officers conducting basic surveys, and scientific operations 1926-27. Prepared under the direction of W. T. Neill, Surveyor-General. Wellington, W. A. G. Skinner, Govt. Printer, 1928 (118 with pls. and maps). 34 cm. [Contains a report on the Christchurch Magnetic Observatory by H. F. Skey, with tables giving the hourly values of the three magnetic elements for 1926, and of declination and horizontal intensity for 1906.]

B—Terrestrial and Cosmical Electricity

Brenton, R. S. Unusual thunderstorm phenomena. Met. Mag., London, v. 63, July, 1928 (135-137). [Discusses the "vit" or "click" sound accompanying lightning, interval between flashes and the corresponding thunder, etc., with comments by R. M. Poulter and R. L. Best.]

Brillouin, M. Questions d'électricité atmosphérique. Atti, Cong. Internat. Fisici, Settembre 1927, v. 1, Bologna, 1928 (377-392).

Brooks, C. F. The great aurora and magnetic storm of July 7-8, 1928. Bull. Amer. Met. Soc., Worcester, Mass., v. 9, Aug.-Sept., 1928 (134).

Dauzère, C., et J. Bouget. Influence de la constitution géologique du sol sur les points de chute de la foudre. Paris, C.-R. Acad. sci., T. 186, No. 23, 1928 (1565-1566).

Sur l' ionisation intense de l'air dans les lieux fréquemment foudroyés. Paris, C.-R. Acad. sci., T. 186, No. 25, 1928 (1744-1746).

Dillard, E. W. Lightning investigation on New England Power Company System. New York, J. Amer. Inst. Elec. Engin., v. 47, July, 1928 (489-491).

G., A. L'imitation, en petit, de certaines caractéristiques des aurores boréales. Nature, Paris, No. 2789, 15 juillet 1928 (74-75).

Harper, W. E. The northern lights; what they are. Toronto, J. R. Astr. Soc. Can., v. 22, No. 6, 1928 (234-238). [Radio talk given over CFCT, Victoria, B. C., Apr. 25, 1928.]

Henderson, J. P. Strange behaviour of a lightning stroke. Toronto, J. R. Astr. Soc. Can., v. 22, No. 6, 1928 (242-244).

Hollingworth, J. The polarisation of radio waves. London, Proc. R. Soc., A, v. 119, No. 782, 1928 (444-464).

Hulburt, E. O. The high atmosphere of the Earth. Sci. Mon., New York, N. Y., v. 27, Aug., 1928 (134-137). [The article deals with our knowledge of the upper atmosphere as revealed by wireless waves.]

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Jouaust, R. Les phénomènes de propagation des ondes radiotélégraphiques. Paris, C.-R. Acad. sci., T. 187, No. 4, 1928 (208-209).

Lutz, C. W. Das normale luftelektrische Potentialgefälle in München 1906-1925. München, SitzBer. Ak. Wiss., Jahrg. 1928 (19-36).

McLennan, J. C. The aurora and its spectrum. Abstract: Nature, London, v. 122, July 7, 1928 (38-39).

Perschke, W. Zur Frage nach dem Ursprung der durchdringenden Strahlung. Zs. Physik, Berlin, Bd. 49, Heft 9-10, 1928 (740-741). [In der vorliegenden Arbeit wird gezeigt, dass zur Klärung der durchdringenden Strahlung die Tatsache der Bildung von Heliumatomen aus Wasserstoffatomen vollkommen ausreicht.]

Pickard, G. W. Concerning lunar effects on electromagnetic waves. QST, Hartford, Conn., v. 12, Aug., 1928 (20).

Sanford, F. Observations on solar and lunar diurnal variations of earth potential due to changes in distribution of the Earth's surface-charge, including two new methods of recording such variations, and on the accompanying variations in the atmospheric potential-gradient for the year 1927. Bull. Terr. Electr. Obs., Palo Alto, Cal., v. 5, 1928, 26 pp.

A new arrangement for showing the diurnal variation in the intensity of the Earth's surface-charge at a given place. Science, New York, N. Y., v. 68, July 20, 1928 (64-65).

Tyndall, A. M. Carriers of electricity in the atmosphere. London, Proc. R. Inst., Apr. 27, 1928, 3 pp. Nature, London, v. 122, July 7, 1928 (16-17).

Van der Pol, B. Enkele physische beschouwingen over ultra-korte golven, mede in verband met de uitzendingen van het Philips' Radio-laboratorium. Ingenieur, 's-Gravenhage, No. 46, 1927, 27 pp.

C—Miscellaneous

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Asakura, J., and S. Fujiwhara. On the continuous record of atmospherics and its diurnal oscillations. (Preliminary report.) Geophys. Mag., Tokyo, v. 1, No. 5, 1928 (233-237). [Curves of the diurnal variation of the magnetic elements at Kakioka, of the potential gradient at Tokyo, and of atmospherics observed in Tokyo, are compared.]

Ault, J. P. The new cruise of the "Carnegie." Discovery, London, v. 9, July, 1928 (226-228).

Ball, J. D. Effect of methods of demagnetization on the energy required to magnetize steel. Philadelphia, Pa., J. Frank. Inst., v. 206, Aug., 1928 (181-200).

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International Geodetic and Geophysical Union. Union Géodésique et Géophysique Internationale. Troisième assemblée générale réunie à Prague du 3 au 10 septembre 1927. Toulouse, Imprimerie et Librairie Edouard Privat., 1927, 117 pp. 25 cm. [Contient: Procès-verbaux des séances, avec appendices: I. Pays adhérents à l'Union (septembre 1927); II. Liste des délégués et des membres invités; III. Composition des comités nationaux des pays adhérents.]

Lee, E. S. Cathode-ray oscillographs and their uses. Principle of the cathode-ray oscillograph, fundamental types, characteristics, description of instrument, examples of application. Gen. Elec. Rev., Schenectady, N. Y., v. 31, Aug., 1928 (404-412).

MacMillan, D. B. Etah and beyond or life within twelve degrees of the Pole. London, Chapman and Hall, Ltd., 1928 (xix+287 with illus.). 22 cm. [Contains brief references to the magnetic work done during the expedition and two views of the magnetic observatory at Refuge Harbor where registrations of the magnetic elements were obtained.]

Nodon, A. La radioactivité est-elle d'origine cosmique? Nature, Paris, No. 2788, 1er juillet 1928 (16).

India, Survey of. General report 1926 to 1927. Published by order of Colonel Commandant E. A. Tandy, R. E., Surveyor General of India. Calcutta, 1927 (vi+95 with maps). 26 cm. Bd. [Covers period from October 1, 1926 to September 30, 1927. Contains no magnetic results.]

Roy, M. M. Recherches sur la radioactivité de l'atmosphère. (Thèse pour obtenir le titre de Docteur de l'Université de Paris, 1928.) Paris, Les Presses Universitaires de France, 1928, 42 pp. 25 cm.

Schmid, F. Das Zodiakallicht. Sein Wesen, seine kosmische oder tellurische Stellung. Hamburg, Verlag von Henri Grand, 1928 (x+132 mit 1 mehrfarbigen Titelbilde, 22 Abb. im Text, 3 Tafeln u. 3 Tabellen). 23 cm.

Stokley, J. Three years abaft the mast. What the non-magnetic ship "Carnegie" is doing for science on her three-year cruise. Sci. Amer., New York, N. Y., v. 139, Sept., 1928 (240-243 with illus.).

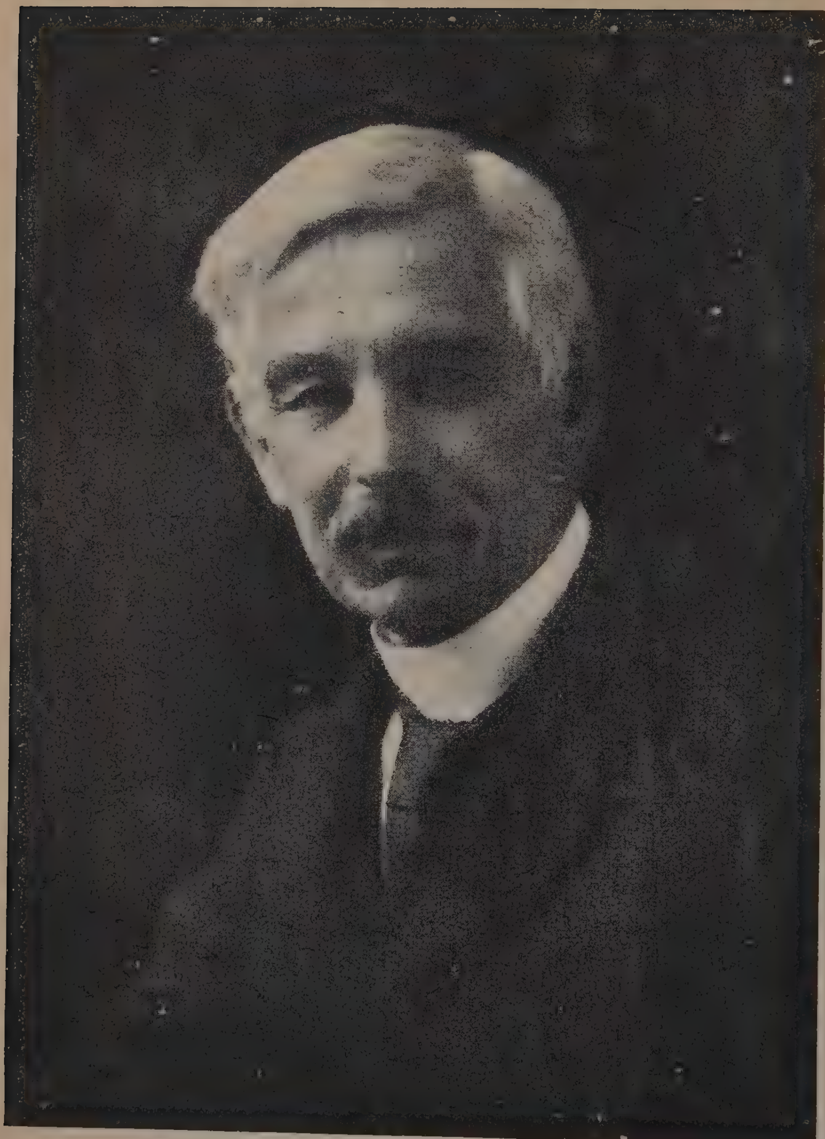
Thompson, D'A. W. The Geophysical Institute at Bergen. Nature, London, v. 122, July 21, 1928 (98-100).

Thomson, J. J. Beyond the electron. A lecture given at Girton College on 3 March 1928. Cambridge, University Press, 1928, 43 pp. 19 cm. [An excellent exposition of the present status of the subject. The mathematical treatment of theories is contained in two appendices.]

Whittaker, E. T. The influence of gravitation on electro-magnetic phenomena. Nature, London, v. 121, June 30, 1928 (1022-1024).

Wimperis, H. E., and F. E. Smith. Physics in industry. Lectures delivered before the Institute of Physics. Volume 5. London, Oxford University Press, 1927, 54 pp. 24 cm. [Contains: The relationship of physics to aeronautical science, by H. E. Wimperis, and Physics in navigation. by F. E. Smith. In the latter lecture is a discussion of the magnetic compass, pp. 33-38.]

[Plate II]



Yours sincerely
C Chree

Terrestrial Magnetism
and
Atmospheric Electricity

VOLUME 33 DECEMBER, 1928 No. 4

CHARLES CHREE[1]

BY S. CHAPMAN

Charles Chree, for many years one of the most eminent and indefatigable workers on terrestrial magnetism, died on August 12, 1928, after an illness, patiently and bravely borne, lasting for several months.

He was the second son of the Rev. Charles Chree, D.D., minister of Lintrathen in Forfarshire, a country parish a few miles from Kirriemuir—Barrie's "Thrums"; he was born on May 5, 1860. He was educated at the Grammar School, Old Aberdeen, and at the Universities of Aberdeen, where he gained distinction in classics as well as in mathematics and physics, and Cambridge. At the latter he was sixth wrangler in 1883, and also took a first-class in the Natural Science Tripos, Part 2. In 1885, he was elected to a fellowship, extended in 1890 as a research fellowship, at King's College, where he had been a mathematical scholar. He worked in the Cavendish Laboratory, and wrote many papers, to which numerous references may be found in Love's treatise, on the mathematical theory of elasticity.

In 1893 he was appointed Superintendent of Kew Observatory, where his main lifework was done. He held the office for thirty-two years, retiring in 1925 on attaining the age-limit. During the earlier part of his tenure he was responsible for the testing of thousands of chronometers, watches, clinical thermometers, and similar instruments—duties subsequently transferred to the newly-founded National Physical Laboratory. His principal work, however, was the execution or supervision of the magnetic, atmospheric-electric, and meteorological observations, which also he discussed with great care and minuteness in a long series of memoirs. While this was henceforward his main occupation, he retained his interest

[1]The portrait of Dr. Chree, from which the frontispiece was made, was kindly supplied by Dr. G. C. Simpson, Director of the Meteorological Office, London.

in the theory of elasticity, and so late as 1904 published an important paper on the whirling and transverse vibration of rotating shafts.

Besides investigating the data obtained at Kew, he undertook the reduction and discussion of several series of Antarctic magnetic observations, a monumental task of great service to magnetic science, and one which no one was better fitted to perform than he. He also wrote freely on current topics engaging the attention of magneticians, such as the magnetic characterization of days, solar and magnetic relationships, and the simultaneity of sudden commencements of magnetic disturbance. He was particularly interested in the phenomenon which he called the "non-cyclic variation" of the magnetic elements, and which he independently discovered.

Probably his best original work, as distinct from his valuable and solid labours of observation and discussion on more or less standard lines, was his demonstration of the 27-day recurrence-tendency shown by the magnetic conditions. Maunder, in 1904, brought forward strong evidence of this tendency in relation to magnetic storms, and gave the now accepted interpretation of it as due to the action upon the Earth of long-continuing streams of corpuscles emitted from locally disturbed regions on the rotating Sun. Chree, like others at the time, was sceptical, but later he gave the best available demonstration of the tendency, and showed that it applies to relative absence of disturbance as well as to excess of disturbance above the mean. His beautiful and simple method utilized the daily magnetic character-figures, and illustrated the value of the international scheme by which these figures are provided at de Bilt. Chree's method, and his 27-day "pulse-diagrams," are a permanent enrichment of terrestrial magnetic science.

He was a voluminous writer, having published about a hundred and fifty memiors, papers, and articles, besides his large volumes on Antarctic data. In 1912 he produced a monograph on his own "Studies in Terrestrial Magnetism." His writings are mines of accurate information, often somewhat too detailed to excite interest except in those who shared his passion for the facts in themselves.

Terrestrial magnetism has proved singularly intractable to theoretical treatment, and its literature is strewn with the wrecks of abandoned hypotheses. Chree's temperment was such that he felt little temptation to venture upon these dangerous waters; perhaps he went too far in the opposite direction, deprecating the

attempt to construct magnetic theories which he regarded as premature and at present not the best means of advancing the science. For this reason his command of mathematical technique scarcely found any scope in his work on terrestrial magnetism. But his critical bent and ability often proved valuable in the discussion of alleged facts of observation, or of proposed theories.

He received many honours, including the degree of Sc.D. at Cambridge (1895), the Hon. LL.D. of Aberdeen (1898), the Fellowship of the Royal Society (1897), and its Hughes Medal in 1919. He served on numerous Councils and Committees: he was President of the Physical Society (1908-1910), and of the Royal Meteorological Society (1922 and 1923). At the time of his death he was President of the Commission for Terrestrial Magnetism and Atmospheric Electricity of the International Meteorological Organization, and had only resigned in September, 1927, from the Presidency of the Section for Terrestrial Magnetism and Electricity of the International Union of Geodesy and Geophysics.

In his younger days he was fond of tennis, cycling, golf, and fishing, and in later life of country walks. His speech, both on public occasions and in conversation, was enlivened by a characteristic humour. He and his sister made their home at Richmond, near the Kew Observatory and within easy reach of London, in whose scientific life he took an active share.

REVIEWS AND ABSTRACTS

(See also pages 209 and 261)

MARIS, H. B., AND E. O. HULBERT: *Comets and terrestrial magnetic storms.* Abstract of communication presented at the December 1928 meeting, American Physical Society.

Practically all observed details of terrestrial magnetic storms have recently been shown to be explainable by the assumption that the solar disturbance is a half-hour ultraviolet flash, such as would come from a spot at 30000°K and 1/10000 of solar disk in size. Such a flash would be expected to cause changes in comets much as it does in our own atmosphere, and we find that this is so. For, in nearly every instance the date on which a comet was observed to undergo an unusual change, such as breaking up of the nucleus, loss of tail, sudden increase in brightness, etc., was found to follow within a week the date on which a strong magnetic storm occurred on the Earth, provided the necessary condition was fulfilled that the Earth and the comet were approximately on the same side of the Sun. When the comet and the Earth were on opposite sides of the Sun, changes in the comet were found to occur between periods of terrestrial magnetic storms separated by a solar rotation. Further, the action of the ultraviolet light of the quiet (undisturbed) Sun on the nucleus is shown to account for some hitherto unexplained characteristics of the tail. AUTHORS

Goldstein, S.: *The influence of the Earth's magnetic field on electric transmission in the upper atmosphere.* London, Proc. R. Soc., A, v. 121, 1928, pp. 260-235.

In this paper the author develops formulas for the problem of the propagation of electromagnetic waves in the general case when the magnetic field is oblique to the direction of propagation. It is found that, in general, a wave penetrating the ionized region is split into two elliptically polarized components traveling with different velocities. The polarization will be right-handed or left-handed according as the imposed magnetic field has a component in the direction of, or opposition to the direction of, propagation of the wave. From the solution for the general case formulas are derived for the special cases of propagation perpendicular or parallel to the magnetic field which are similar to those obtained by other investigators. By considering the manner in which the index of refraction depends on the frequency of the wave and on the electron-density of the medium, the author works out the values of the "forbidden wave-lengths" for which the index of refraction is imaginary.

Numerical examples are worked out on the basis of the values of the Earth's magnetic field in England. It is found that for a wave of 10 km neither of the two components into which the original wave is separated can penetrate to a layer in which N exceeds 580 electrons per cc, while only one component can reach a layer in which N exceeds 11. It is of interest to note here that in the absence of the Earth's field the value of N would be 11 for each component, so that the great extent to which the propagation of long waves is affected by the Earth's field is evident. For a wave length of 1 km the limits of N are found to be 6.8×10^3 and 11×10^2; for a 400-meter wave, 21×10^3 and 6.8×10^3: for a 100-meter wave, 11×10^4 and 5.4×10^4; while for a 20-meter wave they are 2.8×10^6 and 2.5×10^6, respectively.

A study is also made of the polarization of the down-coming wave, and from the difference of the damping of the two components numerical values for their amplitude ratios are worked out. Applying the theory of the experiments of Appleton and Ratcliff leads the author to discriminate between three layers of ionization. For 400-meter waves, the first layer is found to extend from about 100 km downward and to contain not more than about 4×10^3 electrons per cc, this value being sufficient to cause considerable absorption without preventing the rays from penetrating to the higher layers. The second layer is at a height of about 100 km with a maximum concentration of about 2×10^4 electrons per cc at night, which is sufficient to reflect one of the components of the original wave but allows the second component to penetrate to a third layer at a height of about 200 km before it is finally reflected. According to the theory this upper layer would contain about 2×10^6 electrons per cc at night while the regions between it and the middle layer would be but sparsely populated with ions.

A calculation based on the Appleton experiment of the ratio of the energy of the down-coming wave to that of the incident wave gives a value of about 0.29 for west to east transmission and about 0.47 for transmission from south to north. While these values are to be considered as estimates of the upper limits, the ratio, in any case, should be greater for south to north than for west to east transmission.

The paper presents the various equations applying to this problem in a convenient and accessible form. However, further experimental evidence must be obtained before the conclusions in regard to the state of ionization of the upper atmosphere can be considered as valid. L. R. Hafstad

PRELIMINARY RESULTS OF OCEAN MAGNETIC OBSERVATIONS ON THE *CARNEGIE* FROM REYKJAVIK TO BARBADOS TO BALBOA, JULY TO OCTOBER, 1928[1]

BY J. P. AULT, *Commanding the Carnegie*

TABLE 1—*Preliminary Magnetic Results on Cruise VII of Carnegie, Atlantic Ocean, July to September, 1928* (*Observers:* J. P. Ault, O. W. Torreson, F. M. Soule, W. E. Scott, L. A. Jones, and J. H. Paul)

Date	Latitude	Longitude east	*Carnegie*-values			Chart-differences[a]								
						Declination			Inclination			Hor. intensity[b]		
			D	*I*	*H*	Br.	Ger.	U. S.	Br.	Ger.	U. S.	Br.	Ger.	U. S.
1928	° ′	° ′	°	°	*c.g.s.*	°	°	°	°	°	°			
Jul. 27[c]	63 49 N	336 33	31.2W	......	......	+0.6	+1.1	+0.2	.....	.....	.....	.....	.....	.....
28[d]	63 02 N	334 43	30.2W	......	......	+2.5	+3.2	+2.3	.....	.....	.....	.....	.....	.....
28	62 01 N	332 20	33.7W	......	......	−0.2	+0.4	−0.4	.....	.....	.....	.....	.....	.....
29	60 57 N	329 35	......	76.1 N	.125	.....	.....	.....	+0.9	+0.7	+1.1	−6	−6	−9
29	60 12 N	327 29	34.4W	......	......	+0.8	+1.1	+0.4	.....	.....	.....	.....	.....	.....
30	58 43 N	326 00	34.3W	......	......	+0.6	+1.3	+0.2	.....	.....	.....	.....	.....	.....
31	57 49 N	326 00	......	74.3 N	.141	.....	.....	.....	+0.1	−0.1	+0.2	+2	+5	0
31	57 50 N	326 02	33.3W	......	......	+0.8	+1.4	+0.5	.....	.....	.....	.....	.....	.....
Aug. 2	58 18 N	321 46	......	......	.134	.....	.....	.....	.....	.....	.....	0	0	−2
2	58 17 N	321 24	......	75.2 N	......	.....	.....	.....	+0.2	−0.2	+0.2	.....	.....	.....
2	58 12 N	319 26	37.3W	......	......	+0.3	+1.0	−0.1	.....	.....	.....	.....	.....	.....
2	58 08 N	318 16	37.1W	......	......	+0.9	+1.4	+0.5	.....	.....	.....	.....	.....	.....
3	58 02 N	316 32	38.0W	......	......	+0.7	+1.2	+0.1	.....	.....	.....	.....	.....	.....
3	57 57 N	315 09	......	......	.127	.....	.....	.....	.....	.....	.....	0	0	−2
3	57 56 N	314 52	......	76.4 N	......	.....	.....	.....	+0.4	+0.1	+0.3	.....	.....	.....
4	53 56 N	310 45	......	75.3 N	.138	.....	.....	.....	+0.1	−0.1	0.0	+1	−1	0
4	53 40 N	310 43	35.2W	......	......	+0.9	+1.0	0.0	.....	.....	.....	.....	.....	.....
5	52 01 N	310 29	35.7W	......	......	−1.2	−0.9	−2.0	.....	.....	.....	.....	.....	.....
5	50 58 N	310 55	32.3W	......	......	+1.0	+1.5	+0.4	.....	.....	.....	.....	.....	.....
6	49 14 N	311 34	31.0W	......	......	+0.8	+1.1	+0.1	.....	.....	.....	.....	.....	.....
6	48 44 N	311 44	......	72.5 N	.160	.....	.....	.....	−0.1	−0.5	0.0	0	+2	−2
6	47 35 N	312 05	29.6W	......	......	+0.6	+1.3	+0.4	.....	.....	.....	.....	.....	.....
7	46 18 N	311 54	29.1W	......	......	0.0	+0.8	−0.2	.....	.....	.....	.....	.....	.....
7	45 12 N	312 38	27.5W	......	......	+0.9	+1.5	+0.4	.....	.....	.....	.....	.....	.....
8	43 43 N	313 12	26.2W	......	......	+1.2	+1.5	+0.8	.....	.....	.....	.....	.....	.....
8	43 04 N	313 05	......	68.8 N	.185	.....	.....	.....	−0.7	−1.1	−0.3	+1	+2	0
8	42 50 N	313 04	26.1W	......	......	+0.6	+0.9	+0.4	.....	.....	.....	.....	.....	.....
9	41 47 N	312 22	26.3W	......	......	−0.5	−0.2	−0.5	.....	.....	.....	.....	.....	.....
10	40 07 N	311 20	......	67.2 N	.199	.....	.....	.....	−0.4	−1.1	−0.5	+4	+7	+4
10	39 20 N	311 12	23.9W	......	......	0.0	0.0	−0.1	.....	.....	.....	.....	.....	.....
11	38 48 N	311 09	23.7W	......	......	−0.3	0.0	−0.3	.....	.....	.....	.....	.....	.....
11	38 09 N	311 18	23.6W	......	......	−0.5	−0.2	−0.5	.....	.....	.....	.....	.....	.....
12	37 11 N	311 27	22.8W	......	......	−0.3	+0.2	−0.4	.....	.....	.....	.....	.....	.....
12	36 54 N	312 00	......	65.3 N	.208	.....	.....	.....	+0.1	−0.6	−0.2	+1	+2	−1

[a]Charts used for comparison: U. S. Hydrographic Office charts 1700, 1701, and 2406 for 1925; British Admiralty charts 775 for 1927, 3598 and 3603 for 1922; Reichs-Marine-Amt. charts Tit. XIV, 2, 2a, and 2b for 1920. All chart-values have en corrected to 1928.5 on account of secular-change rate indicated by the respective charts. The chart-differences are obained by subtracting the chart-values from those determined on the *Carnegie*, east declination, north inclination, and orizontal intensity being reckoned as positive and west declination and south inclination as negative.

[b]Expressed in units of third decimal C.G.S.

[d]Probably locally disturbed.

[c]The *Carnegie* was at Reykjavik, Iceland, during July 20 to 27, 1928.

[1]For previous values obtained on Cruise VII, see *Terr. Mag.* v. 33, pp. 121-128.

Date	Latitude	Longitude east	*Carnegie*-values			Chart-differences[a]								
						Declination			Inclination			Hor. intensity[b]		
			D	*I*	*H*	Br.	Ger.	U. S.	Br.	Ger.	U. S.	Br.	Ger.	U. S.
1928	° ′	° ′	°	°	*c.g.s.*	°	°	°	°	°	°			
Aug. 12	36 49 N	312 23	23.1W	......	......	−0.5	−0.1	−0.8	.....	.....	.....	.....	.....	.....
13	36 48 N	313 35	23.2W	......	......	−0.5	0.0	−0.6	.....	.....	.....	.....	.....	.....
13	36 27 N	314 01	23.1W	......	......	−0.5	+0.1	−0.6	.....	.....	.....	.....	.....	.....
14	35 34 N	314 58	22.7W	......	......	−0.3	+0.1	−0.6	.....	.....	.....	.....	.....	.....
14	35 19 N	315 28	......	63.2 N	.217	.....	.....	.....	+0.3	−0.6	−0.1	+2	+1	0
14	34 56 N	316 22	22.8W	......	......	−0.5	0.0	−0.8	.....	.....	.....	.....	.....	.....
15	33 52 N	317 30	22.6W	......	......	−0.6	−0.2	−0.8	.....	.....	.....	.....	.....	.....
15	33 08 N	317 55	22.2W	......	......	−0.5	−0.2	−0.6	.....	.....	.....	.....	.....	.....
16	31 40 N	318 39	21.6W	......	......	−0.4	−0.1	−0.6	.....	.....	.....	.....	.....	.....
16	31 23 N	318 48	......	......	.234	.....	.....	.....	.....	.....	.....	+4	+1	+1
16	31 08 N	318 57	......	58.3 N	......	.....	.....	.....	−0.1	−1.3	−0.7	.....	.....	.....
16	30 25 N	319 06	21.2W	......	......	−0.4	0.0	−0.6	.....	.....	.....	.....	.....	.....
17	29 54 N	319 22	21.5W	......	......	−0.9	−0.3	−1.0	.....	.....	.....	.....	.....	.....
17	29 26 N	319 35	21.1W	......	......	−0.7	−0.1	−0.7	.....	.....	.....	.....	.....	.....
18	28 26 N	320 06	20.8W	......	......	−0.6	−0.1	−0.6	.....	.....	.....	.....	.....	.....
18	27 20 N	320 55	20.7W	......	......	−0.8	−0.3	−0.6	.....	.....	.....	.....	.....	.....
19	25 46 N	321 08	......	52.7 N	.257	.....	.....	.....	+0.1	−0.8	−0.1	+7	+7	+4
19	25 19 N	320 45	20.4W	......	......	−1.0	−0.6	−0.9	.....	.....	.....	.....	.....	.....
20	24 12 N	320 27	20.2W	......	......	−1.0	−0.6	−1.0	.....	.....	.....	.....	.....	.....
20	23 27 N	320 09	19.8W	......	......	−0.9	−0.6	−0.8	.....	.....	.....	.....	.....	.....
21	22 20 N	320 14	19.6W	......	......	−0.9	−0.7	−0.7	.....	.....	.....	.....	.....	.....
21	22 00 N	320 19	......	49.3 N	.268	.....	.....	.....	−0.2	−1.1	−0.5	+10	+8	+7
21	21 12 N	320 36	19.6W	......	......	−1.0	−1.0	−0.9	.....	.....	.....	.....	.....	.....
22	19 22 N	321 30	19.4W	......	......	−1.0	−0.9	−0.8	.....	.....	.....	.....	.....	.....
22	18 36 N	321 43	19.3W	......	......	−1.0	−0.9	−0.7	.....	.....	.....	.....	.....	.....
23	17 05 N	322 05	19.3W	......	......	−1.1	−1.0	−0.8	.....	.....	.....	.....	.....	.....
23	16 44 N	322 09	......	42.2 N	.283	.....	.....	.....	−0.5	−1.1	−1.1	+10	+7	+9
23	16 13 N	322 09	19.2W	......	......	−1.1	−0.8	−0.8	.....	.....	.....	.....	.....	.....
25	14 53 N	321 50	......	40.2 N	.286	.....	.....	.....	−0.3	−1.6	−1.5	+11	+8	+8
26	13 55 N	321 58	19.0W	......	......	−1.3	−1.0	−0.9	.....	.....	.....	.....	.....	.....
27	13 27 N	322 00	19.0W	......	......	−1.4	−1.1	−0.9	.....	.....	.....	.....	.....	.....
28	12 08 N	322 07	18.8W	......	......	−1.3	−0.9	−0.8	.....	.....	.....	.....	.....	.....
28	12 01 N	322 07	......	36.1 N	.291	.....	.....	.....	−0.6	−1.5	−1.5	+10	+8	+8
29	10 47 N	322 43	18.7W	......	......	−1.2	−0.7	−0.6	.....	.....	.....	.....	.....	.....
30	9 37 N	322 50	......	32.0 N	.295	.....	.....	.....	−0.2	−2.2	−1.5	+9	+8	+7
30	9 14 N	323 14	18.9W	......	......	−1.1	−0.9	−0.7	.....	.....	.....	.....	.....	.....
31	8 12 N	323 42	19.5W	......	......	−1.6	−1.3	−1.2	.....	.....	.....	.....	.....	.....
Sep. 1	9 10 N	323 23	19.1W	......	......	−1.3	−0.9	−0.8	.....	.....	.....	.....	.....	.....
1	9 16 N	323 22	......	31.1 N	.296	.....	.....	.....	−0.4	−2.1	−1.1	+10	+8	+8
2	9 39 N	323 26	18.9W	......	......	−1.1	−0.7	−0.6	.....	.....	.....	.....	.....	.....
3	10 56 N	322 53	18.8W	......	......	−1.1	−0.7	−0.6	.....	.....	.....	.....	.....	.....
4	11 18 N	322 30	18.8W	......	......	−1.2	−0.8	−0.7	.....	.....	.....	.....	.....	.....
4	11 21 N	322 11	......	35.2 N	.291	.....	.....	.....	−0.4	−1.7	−1.6	+9	+7	+7
4	11 26 N	321 20	18.2W	......	......	−1.0	−0.8	−0.5	.....	.....	.....	.....	.....	.....
5	11 32 N	319 33	17.7W	......	......	−1.2	−1.0	−0.9	.....	.....	.....	.....	.....	.....
5	11 35 N	318 42	17.5W	......	......	−1.4	−1.1	−1.2	.....	.....	.....	.....	.....	.....
6	11 41 N	317 44	17.1W	......	......	−1.3	−1.0	−1.5	.....	.....	.....	.....	.....	.....
6	11 37 N	317 15	......	38.7 N	.287	.....	.....	.....	−0.7	−1.1	−1.5	+9	+6	+7
6	11 33 N	317 03	16.9W	......	......	−1.4	−1.2	−1.5	.....	.....	.....	.....	.....	.....
7	11 22 N	315 57	16.4W	......	......	−1.5	−1.2	−1.5	.....	.....	.....	.....	.....	.....
7	11 22 N	315 28	16.0W	......	......	−1.3	−1.1	−1.4	.....	.....	.....	.....	.....	.....
8	11 33 N	314 58	15.7W	......	......	−1.3	−1.1	−1.3	.....	.....	.....	.....	.....	.....

Date	Latitude	Longitude east	*Carnegie*-values			Chart-differences[a]								
						Declination			Inclination			Hor. intensity[b]		
			D	I	H	Br.	Ger.	U. S.	Br.	Ger.	U. S.	Br.	Ger.	U. S.
1928	° ′	° ′	°	°	c.g.s.	°	°	°	°	°	°			
Sep. 8	11 35 N	314 55	...	40.0 N	287	...	...	...	−0.2	−0.8	−0.9	+10	+6	+8
9	11 40 N	314 16	15.4 W	...	...	−1.3	−1.1	−1.2	...	...	...	...	...	...
9	11 39 N	313 33	15.0 W	...	...	−1.3	−1.2	−1.3	...	...	...	...	...	...
10	11 58 N	312 32	...	41.4 N	.285	...	...	...	−0.3	−1.1	−0.6	+9	+5	+7
11	13 05 N	310 31	13.7 W	...	...	−1.3	−1.2	−1.3	...	...	...	...	...	...
11	13 13 N	310 05	13.6 W	...	...	−1.4	−1.3	−1.3	...	...	...	...	...	...
12	13 10 N	309 33	...	44.1 N	.281	...	...	...	−0.1	−0.2	−0.3	+8	+2	+6
12	13 11 N	309 04	12.9 W	...	...	−1.2	−1.0	−1.3	...	...	...	...	...	...
13	13 14 N	307 55	12.0 W	...	...	−0.9	−0.7	−0.8	...	...	...	...	...	...
13	13 14 N	307 15	11.7 W	...	...	−0.9	−0.8	−0.9	...	...	...	...	...	...
14	13 08 N	306 13	11.0 W	...	...	−0.8	−0.9	−0.6	...	...	...	...	...	...
14	13 02 N	305 28	...	44.9 N	.282	...	...	...	0.0	−0.7	−0.2	+8	+2	+7
14	13 00 N	305 11	10.4 W	...	...	−0.8	−0.9	−0.7	...	...	...	...	...	...
15	12 55 N	303 57	9.3 W	...	...	−0.5	−0.4	−0.3	...	...	...	...	...	...
15	12 56 N	303 12	9.1 W	...	...	−0.7	−0.7	−0.5	...	...	...	...	...	...
16	13 02 N	302 00	8.2 W	...	...	−0.5	−0.4	−0.4	...	...	...	...	...	...
16	13 01 N	301 45	...	45.6 N	.283	...	...	...	+0.2	+0.1	+0.3	+9	−2	+6
16	13 00 N	301 08	7.7 W	...	...	−0.5	−0.4	−0.3	...	...	...	...	...	...
Oct. 1[e]	13 26 N	299 59	7.0 W	...	...	−0.4	−0.1	−0.5	...	...	...	...	...	...
2	14 22 N	298 59	6.3 W	...	...	+0.1	+0.2	+0.1	...	...	...	...	...	...
2	14 42 N	298 17	...	48.1 N	.282	...	...	...	+0.9	+0.1	+0.9	+9	0	+7
2	14 44 N	297 56	6.2 W	...	...	−0.3	−0.3	−0.4	...	...	...	...	...	...
3	14 46 N	296 43	5.6 W	...	...	−0.4	−0.5	−0.5	...	...	...	...	...	...
4	15 00 N	294 07	...	47.9 N	.286	...	...	...	+0.3	−0.5	+0.6	+8	+1	+7
4	15 06 N	293 18	3.4 W	...	...	0.0	−0.5	−0.2	...	...	...	...	...	...
5	15 15 N	292 00	2.4 W	...	...	+0.4	−0.1	0.0	...	...	...	...	...	...
5	15 20 N	291 16	2.1 W	...	...	+0.2	−0.1	+0.1	...	...	...	...	...	...
6	15 13 N	289 28	0.7 W	...	...	+0.6	+0.2	+0.3	...	...	...	...	...	...
6	15 11 N	289 04	...	47.9 N	.291	...	...	...	+0.7	+0.3	+0.6	+5	0	+6
6	15 06 N	288 14	0.1 W	...	...	+0.5	+0.3	+0.1	...	...	...	...	...	...
7	14 49 N	286 33	1.1 E	...	...	+0.7	+0.2	+0.4	...	...	...	...	...	...
7	14 42 N	286 18	...	46.9 N	.296	...	...	...	+1.0	+0.7	+0.7	+4	0	+4
7	14 15 N	285 24	1.6 E	...	...	+0.4	−0.5	+0.4	...	...	...	...	...	...
8	13 41 N	283 51	2.6 E	...	...	+0.4	−0.3	+0.4	...	...	...	...	...	...
8	13 05 N	283 04	3.0 E	...	...	+0.3	−0.1	+0.3	...	...	...	...	...	...
9[f]	11 48 N	281 46	3.8 E	...	...	+0.1	−0.2	+0.1	...	...	...	...	...	...
9	11 39 N	281 39	...	41.4 N	.311	...	...	...	+1.3	+0.1	+0.9	+4	+1	+3
10	9 56 N	280 34	4.8 E	...	...	+0.4	+0.2	+0.3	...	...	...	...	...	...

[e]The *Carnegie* was at Barbados, West Indies, during September 16 to October 1, 1928.

[f]The British Admiralty chart-values for October 9 and 10 are taken from chart No. 3777 for 1927.

Notes on Trip From Reykjavik, Iceland to Barbados, West Indies, July 27 to September 17, 1928

The *Carnegie* left Reykjavik at noon on July 27, 1928, going out under her own power against a head-wind. By 14^h the entrance point of the bay was cleared. Heading down toward Cape Farewell, good progress was made for the first four days. On July 31 the winds became unfavorable, and on the next day they went calm and it was necessary to operate the engine. By August 3 the wind had sprung up from the northeast and was blowing a strong breeze. When opposite Cape Farewell, course was set toward Newfoundland, omitting the loop toward Baffin Bay in order to gain on the schedule.

The aurora was seen during the nights of August 3, 4, 5, and 6. High arches went clear across the sky, with some streamers but very little color. On August 5 an iceberg was sighted at a distance of 10 miles and course was changed to pass near. It measured 400 feet long and 95 feet high. After crossing, on August 6, the Great Bank of Newfoundland, an ocean-station on the edge of the Bank with 130 meters of water, was occupied August 7. The temperature of the water at a depth of 52 meters was —1°.6 C, being 11°.4 C at the surface.

For over two weeks the vessel made her way southward, averaging about 140 miles per day, heaving to for an ocean-station three times per week, and entered the Gulf Stream on August 8, to be greeted with much warmer weather. On August 10 a gale blew from the southwest for a few hours, otherwise this period up to August 23 was marked by fine weather and moderate breezes.

On Agust 23 the region of light winds and calms, at latitude 16° north, was entered. For twelve days the average run was only 65 miles daily, with 97 miles as a maximum. During this time the new boom-walk was tried out and dip-nets and silk tow-nets were used from it to good advantage. Various bottom-samplers were tried out under favorable conditions; two samplers were lost because of a faulty wire.

On August 31 in 8° north latitude because of delay through calms it was decided to change course for Barbados. Light air and calms continued until September 10, when a moderate gale blew from the southwest, the wind having changed from northeast to northwest back to north by east, then back again through northwest to southwest. This was undoubtedly the effect of the hurricane which three days later was centered over the Mona Island

Passage which wrought such serious damage throughout the West Indies.

The Island of Barbados was sighted late in the afternoon of September 16. After remaining hove to off the south point of the island nearly all night, anchorage was made in Carlisle Bay at $8^h 30^m$ on the morning of September 17, only three days behind scheduled date of arriving there.

The results obtained from Reykjavik to Barbados included 77 declinations, 25 values of both inclination and horizontal intensity, 22 ocean-stations, 205 sonic depths, and six complete and three incomplete potential-gradient diurnal-variation series. Evaporation-observations were made on three days. Thus excellent series of observations were made in all the various subjects. Especially valuable will be the hydrographic section, practically through the center of the North Atlantic, between latitudes 46° north and 8° north. Temperature, salinity, density, specific-volume, hydrogen-ion concentration, and phosphate-content variations from the surface down to a minimum of 2,000 meters and a maximum of 5,500 meters were determined. Plankton-tows were made at surface, 60, and 120 meters with silk tow-nets, and the Petersson plankton-pump was operated at the same depths, at all ocean-stations.

Thus the first long passage of the cruise was completed in a satisfactory manner. The members of the party stood up well under the trying and strenuous conditions attending such a period. The equipment stood up well, with the few exceptions noted separately.

Notes on Trip From Barbados, West Indies, to Balboa, Canal Zone, October 1 to 11, 1928

Leaving the Bridgetown mooring buoy at $11^h 30^m$, October 1, 1928, under her own power, the *Carnegie* headed up northwest to sight Martinique for a fine view of this mountainous island the next day, Mont Pelée showing up clear except for a cloud-bank at the top. For one brief moment the mist lifted enough to see the jagged peaks at the top of the cone against the white cloud-background. After squaring away for Colon at noon October 2, fine weather, with occasional squalls with heavy rain and lightning and thunder, prevailed to within 24 hours' sail of Colon. One squall took the vessel at 11 knots for two hours. The last 24 hours were made under power, calms, and head-winds. Anchorage in

Limon Bay was made at 4^h on the morning of October 11. Proceeding through the Canal October 11, the vessel docked successfully in the dark upon arrival at Balboa after 19^h.

At the first ocean-station a good bottom-sample was secured on the long water-sample series, using the Vaughan sampler. At the next station, after hauling in 700 meters of the first series, the first bottles jammed against the davit-block and before the winch could be stopped, the wire parted. Four thousand meters of wire, 11 Nansen bottles, 5 unprotected and 17 protected Richter deep-sea reversing thermometers, and the second Vaughan snapper-type sampler were lost. During work at an ocean-station two half-meter nets are put out and towed from the after davit on the port side, one one-meter net is towed from the starboard side, at the stern, the plankton-pump is operated from one side-platform using port reel of heavy wire, and the thermometers series are operated from the other platform. At times the pump is being lowered while the bottles are being brought up, or vice versa. The tow-nets are being hauled in with wire around the gypsy-head, and reeled onto hand-reel by hand, while the second bottle series is being brought up, water-samples are being drawn off, thermometers are being taken off bottles and carried to control-room to be read later in the shade. Thus the fraction of a second lost in signalling to shut off the current when a bottle came to the surface caused the loss. A thimble was clamped on the broken end of the cable and some bottles were sent down to 1650 meters, all the wire left on the drum. The next day 700 meters of the 6-millimeter wire were spliced on the end of the 1650-meter length, using one bottle at end, and next bottle above the splice, with messenger with chain long enough to reach below the splice. The reel of spare wire will be wound on the winch at Balboa.

Totals of four ocean-stations, fifteen declination, five inclination and horizontal-intensity, and twenty-nine sonic-depth stations were occupied. No atmospheric-electric run was made because of rainy weather and leaky ion-counter. Radio contact with station 1*MK* was maintained as usual, and station *NKF* was overheard on several nights working the Byrd-Expedition vessels. The biological and chemical work was carried on successfully.

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AURORAL WORK IN SOUTHERN NORWAY SINCE 1922

By Carl Störmer

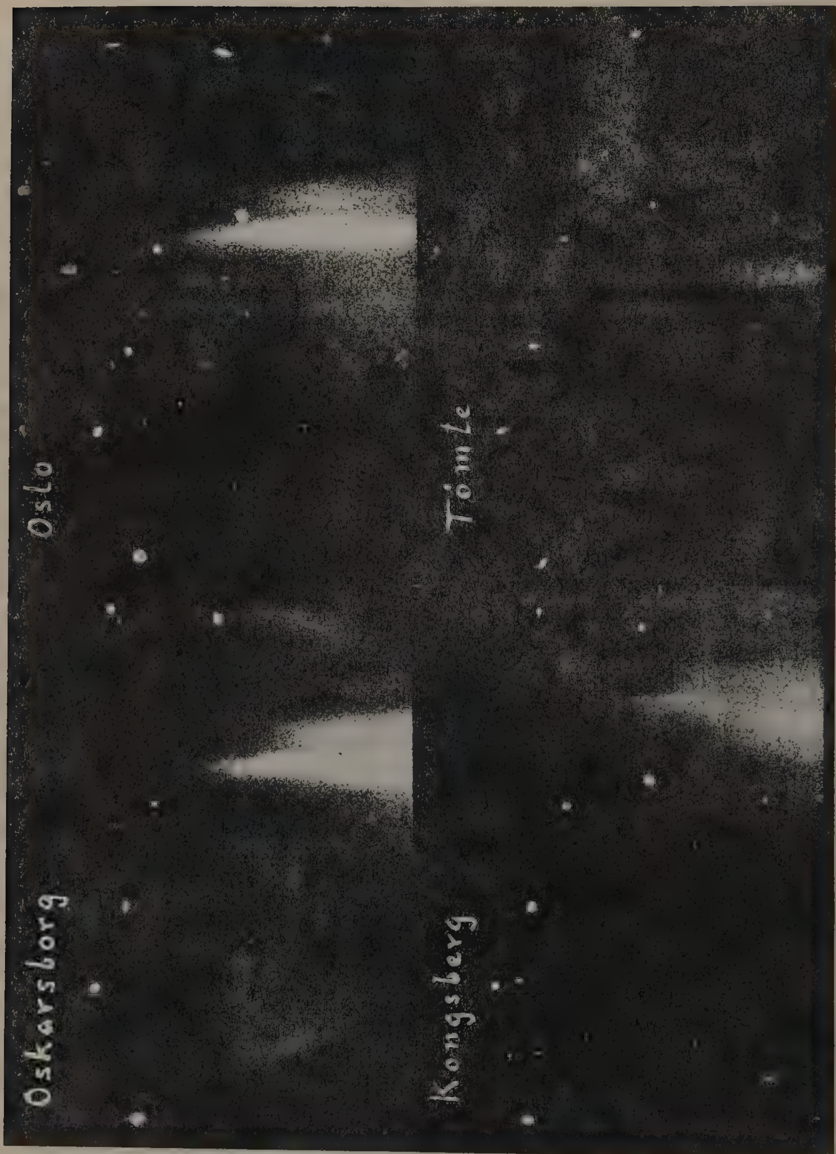
In *Nature* of June 19, 1926, January 8, and September 3, 1927, I gave some results of the photographic work on the aurora borealis from my stations in southern Norway. The complete results for the period 1911 to 1922 have been published in detail in *Geofysiske Publikasjoner*[1]. Since 1922 observers at six stations have been making photographic determinations of the height and situation of the aurora. The following table summarizes the collected material from photographs, arranged chronologically, corresponding to the dates when aurora were photographed. Column I gives the number of successful photographs from one station only; column II shows the number of pairs of photographs taken simultaneously from two stations in telephonic communication to determine the height and situation of the aurora; column III shows the number of successful simultaneous photographs taken from three stations, and column IV the number from four stations.

Date	Number of auroral photographs			
	I	II	III	IV
Oct. 16, 1923	31	39	7	..
Nov. 24, 1924	..	6	..	..
Dec. 20, 1924	3	..	..	..
Jan. 16, 1925	2	..	..	..
Jan. 19, 1925	6	19	..	..
Feb. 19, 1925	5	..	..	..
Oct. 9, 1925	3	..	..	..
Nov. 8, 1925	20	10	..	..
Nov. 10, 1925	12	29	1	..
Jan. 26, 1926	29	19	..	..
Feb. 24, 1926	3	..	..	..
Mar. 3, 1926	3	..	..	..
Mar. 5, 1926	20	35	4	..
Mar. 9, 1926	3	3	..	..
Mar. 13, 1926	4	..	..	..
Mar. 19, 1926	..	11	..	..
May 3, 1926	6	..	..	..
Sep. 7, 1926	2	..	..	..
Sep. 8, 1926	..	14	..	..
Sep. 14, 1926	6	1	..	..
Sep. 15, 1926	30	14	..	..
Sep. 16, 1926	..	4	..	..
Oct. 15, 1926	51	56	4	..
Nov. 28, 1926	18	24	9	..
Dec. 23, 1926	2	..	..	..
Nov. 29, 1927	..	1	..	..
Dec. 13, 1927	1	52	3	..
Mar. 11, 1928	1	5	1	..
Mar. 13, 1928	3	29	..	..
May 11, 1928	9	..	..	..
Aug. 26, 1928	11	27	26	..
Sep. 7, 1928	4	10	2	..
Sep. 18, 1928	1	7	27	7
Totals....	279	415	84	7

Of this extensive material the plates for 1926 and 1927 are being measured and calculated, and the work will probably be finished within a year.

We will give here only four interesting photographs of the same auroral rays, with the Great Bear as a background, taken simultaneously from the four stations, Oslo, Oscarsborg, Kongsberg,

[1] Carl Störmer, Resultats des mesures photogrammétriques des aurores boréales observées dans la Norvège Méridionale de 1911 à 1922. *Geofys. Pub.*, v. 4, No. 7, 1926.



FIGS. 1 TO 4—Simultaneous photographs of auroral rays at four stations, Oslo, Oscarsborg, Kongsberg, and Tömte at $20^h\ 58^m\ 48^s$ Greenwich mean time September 18, 1928, with the Great Bear as a background

and Tömte at $20^h\ 58^m\ 48^s$ Greenwich mean time on September 18, 1928.

The azimuth (reckoned from south through west) and distance from the first to the second station for each pair of these stations have the following values: Oslo to Oscarsborg, 13° 01′, 27.36 km;

Oslo to Kongsberg, 66° 10′, 65.70 km; Oslo to Tömte, 204° 08′, 46.68 km; Oscarsborg to Kongsberg, 90° 01′, 53.92 km; Oscarsborg to Tömte, 199° 57′, 73.73 km; Kongsberg to Tömte, 227° 57′, 105.14 km.

At Oslo my assistant, Tveter, took the photograph of the rays while I was occupied by experiments with photographing through filters. The simultaneous photographs at Oscarsborg, Kongsberg, and Tömte were taken by Hafnor, Busengdal, and Carsten Borchgrevink. By inspecting the picture we can see a high ray in the middle between the stars β and γ of the Great Bear on the Kongsberg photograph. On the Tömte photograph this ray is superposed on another more distant one. On the right border of this high ray we chose two points, one near the foot and one near the summit, and the height and situation of these two points were measured and calculated by the method I described in detail in my reports on the aurora expeditions in 1910 and 1913.[2] As we have four stations, the base-lines can be chosen in six different ways and thus a good check obtained. The pictures taken in Oslo and Oscarsborg are the best; they were taken on Sonia E. W. plates from Herzog Bremen; the other two were taken on Gevaert Supersensima, which were not quite so sensitive.

I have made two series of independent measures which have been calculated by my assistant, Wesöe, and which have given the following results:

Base-line	Heights in kilometers			
	Point 1		Point 2	
Oslo to Oscarsborg	364	336	468	543
Oslo to Kongsberg	345	353	487	498
Oslo to Tömte	371	357	562	563
Oscarsborg to Kongsberg	341	353	483	470
Oscarsborg to Tömte	366	349	524	525
Kongsberg to Tömte	357	355	506	513

At all events it is certain that the ray was situated at a very great altitude. If we use the longest base-line, we find by extrapolation that the foot of the ray was at about 345 kilometers and the summit nearly 600 kilometers above the Earth. It is a remarkable fact that this high ray lay in full sunshine. In fact, the boundary between sunlight and dark atmosphere at the situation of the ray was between 300 and 330 kilometers above the Earth.

Thus this ray gives more evidence of the remarkable influence of sunshine on the height of the auroral rays as mentioned in my letter to *Nature*, September 3, 1927.

Bygdö, Norway, October 15, 1928

[2]Bericht über eine Expedition nach Bossekop zwecks photographischer Aufnahmen und Höhenmessungen von Nordlichtern, *Skr. Vid, selsk., Mat.-naturv. Kl.*, No. 17, 1911 (chapter 3); Rapport sur une expédition d'aurore boréale à Bossekop et Store Korsnes pendant le printemps de l'année 1913, *Geofys. Pub.*, v. 1, No. 5, 1921 (chapter 2), and the above-mentioned report in *Geofys. Pub.*, v. 4, No. 7, 1926.

ON THE IMPORTANCE OF AURORAL PHOTOGRAPHS TAKEN FROM ONE STATION

By H. U. Sverdrup

Carl Störmer has, as is well known, developed methods for photographing the aurora from *two* stations and for computing the altitude and the position in space of the aurora from two simultaneous photographs. The principle is very simple. The same points of the aurora are identified on both photographs and azimuth and altitude of these points are determined by means of corresponding coordinates of stars which also appear on the plates. These data, together with known geographic coordinates of the two stations and the exact time when the pictures were taken give data for computing the position in space of every single auroral point. Störmer,[1, 2] Vegard, and Krogness[3] have examined hundreds of such parallactic photographs and some of the most striking results of these interesting investigations will be mentioned here.

(1) The altitude of the lowest part of the aurora is practically constant in the vicinity of the zone of maximum frequency of the aurora, varying somewhat with the form of the aurora and lying between 100 and 110 kilometers above the surface of the Earth.

(2) Auroral streamers reach the greatest altitudes of all auroral forms and the maximum altitude increases with the distance from the zone of maximum frequency.

(3) Homogeneous arches following closely the concentric circles around the point where the magnetic axis of the Earth cuts the Earth's surface. This point, which is not identical with the magnetic pole of the Earth, lies, according to Störmer, in 78° 30′ north latitude and 68° 38′ west longitude.

(4) The radiation-point of coronæ lies below the magnetic zenith. This last result has been derived also from visual observations but photographs allow much more precise determinations of the radiation-point.

It is, I believe, generally assumed that valuable information regarding the position of aurora in space can be obtained only when simultaneous photographs of the same display are taken from two stations which are at least 20 to 30 kilometers apart. However, highly interesting results can be obtained also from photographs which are taken from one station assuming that some of the above mentioned laws are of general validity. This fact is clearly brought out by the discussion of the auroral photographs of the *Maud* Expedition which recently has been published by R. Wesöe.[4] His discussion ought to stimulate and encourage photographic work from one station since this can be carried out much more easily than work from two stations which have to be in communication with each other. I want to draw attention to some features which

[1] Störmer, Carl: Rapport sur une expédition d'aurores boréales à Bossekop et Store Korsnes pendant le printemps de l'année 1913, *Geofys. Publ.* v. 1, No. 5. Kristiania, 1921.

[2] Störmer, Carl: Résultats des mesures photogrammétriques des aurores boréales observées dans la Norvège meridionale de 1911 à 1922. *Geofys. Publ.* v. 4, No. 7. Oslo, 1926.

[3] Vegard, L. and O. Krogness: The position in space of the Aurora Polaris from observations made at the Haldde Observatory, 1913-1914. *Geofys. Publ.* v. 1, No. 1. Kristiania, 1920.

[4] Wesöe, Ragnvald: Aurora Photographs. The Norwegian North Polar Expedition with the *Maud* 1918-1925. Scientific Results, vol. 1, No. 6. Bergen, 1928.

can be studied by means of single photographs of three auroral forms (homogeneous arches, streamers, and coronæ), using Wesöe's results as illustrations.

In Figures 1, 2, and 3 photographs of the western, middle, and eastern parts of an homogeneous arch are reproduced. These photographs were taken on December 14, 1922, between $20^h\ 40^m$ and $20^h\ 45^m$ local mean time, in 73° 22′ north latitude and 172° 54′

FIG. 1—Western end of arch in northern sky, photographed by O. Dahl, December 14, 1922 at $20^h\ 40^m$ (latitude 73° 22′ north, longitude 172° 54′ east), looking towards Corona Borealis, showing sharp lower border and indistinct upper one

FIG. 2—Middle part of arch in northern sky, December 14, 1922 at $20^h\ 42^m$ from same point as Fig. 1, looking towards Ursa Major

FIG. 3—Eastern end of arch in northern sky, December 14, 1922 at $20^h\ 45^m$ from same point as Figs. 1 and 2, looking towards Gemini

FIG. 4—Glow with streamers in northern sky, photographed by F. Malmgren, March 12, 1924 at $1^h\ 55^m$ (latitude 75° 12′ north, longitude 158° 45′ east), looking towards Ursa Major

FIG. 5—Typical corona photographed by H. U. Sverdrup March 11, 1924 at $23^h\ 12^m$ (latitude 75° 12′ north, longitude 158° 45′ east), the lower part showing converging streamers with auroral bands in the upper part

east longitude. Constellations of stars can be recognized in all three pictures. Ursa Major, for instance, is easily seen in the middle one. By means of the known positions of the stars the angular values of altitude and azimuth of a number of selected points along the lower border of the arc can be computed. The horizontal distance from the place of observation to the point on the Earth (N) which lies vertically below the selected auroral point can be found, assuming that the elevation of the arc above the surface of the Earth is the same as found in northern Norway, namely, 110 kilometers. Finally the points N can be plotted on the map since the azimuth of any point N is the same as the azimuth of the corresponding auroral point and since the horizontal distance to N has been determined. Joining the points N with a line, the projection of the lower border of the arch on the Earth's surface is finally found. Regarding details of the computations, reference may be made to Wesöe's article, above cited, and Störmer's original publications so well known in this field.

Here it is sufficient to draw attention to the result which Wesöe has derived from the auroral photographs which are reproduced in Figures 1 to 3. Wesöe's result is illustrated in Figure 6 where the small circles represent the projections of the selected auroral points and the line joining them the direction of the arch. The place of observation is indicated by the larger circle. The dotted lines represent the concentric circles around the magnetic axis of the Earth, θ being the angular distance from the point where axis cuts the Earth's surface. From the figure it is seen that the three photographed parts of the arch really fit very nicely together and that the arch apparently runs as an almost straight line for a length of about 1000 kilometers, following closely the concentric circles around the Earth's magnetic axis. The last result is especially important because it confirms the conclusions at which Störmer arrived by means of parallactic photographs taken on the other side of the globe. Several others photographs of homogeneous arches which also are treated by Wesöe give the same result as evidenced from the map in Figure 7, in which the homogeneous arches are plotted as heavy lines. The direction of the arches over Scandinavia is determined by Störmer on the basis of photographs taken from two stations while the other arches represented in the map are determined by means of single photographs taken on the *Maud* Expedition. It is to be hoped that this map will stimulate

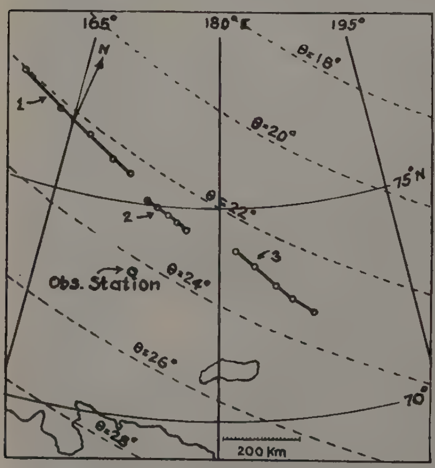


FIG. 6—Map showing plots of arches in Figs. 1, 2, and 3 (directions of the magnetic meridian designated with arrows at points where arches cross the geographic meridians)

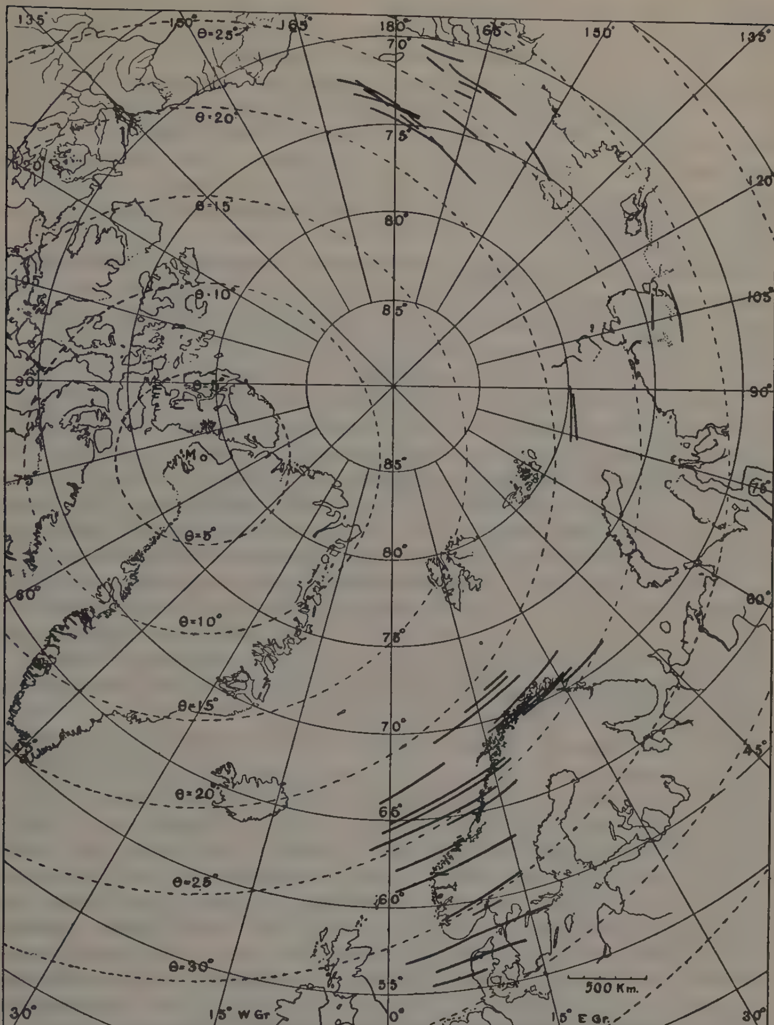


FIG. 7—Directions of homogeneous arches over Norway (Prof. Carl Störmer) and north of Siberia (*Maud*-Expedition)

efforts to fill out the gaps and thus obtain information about the direction of the homogeneous arches all around the globe. This can probably be effected by the simple method of taking single pictures but a number of parallactic photographs from different localities will nevertheless be desirable for ascertaining that the elevation of the arches actually is constant and equal to 110 kilometers as assumed above.

It must be regretted that we did not take many more photographs of arches on board the *Maud*. However, at that time we did not realize the importance of the single photographs for the determination of the direction of arches, but we hoped to be able to

find this from rough eye-observations. The eye-observations indicated[5] that the main direction of the arches coincided with the direction of the magnetic prime vertical which in the region with which we are concerned forms an angle of about 20° with the direction of the concentric circles around the magnetic axis of the Earth. The discrepancy between these two results must probably be attributed to the inaccuracy of our eye-observations which were made subject to rough statistical treatment. The photograph is much more suited for exact determinations although eye-observations can be carried out with greater accuracy than was the case on board the *Maud*.

Photographs of streamers are also of great value and can give results which cannot be derived from eye-observations. Figure 4 shows a number of streamers. This photograph was taken on March 12, 1924, at $1^h\,55^m$ local mean time in 75° 12′ north latitude and 158° 29′ east longitude. Assuming that the lower ends of the streamers are 110 kilometers above the surface of the Earth and that the streamers here, as elsewhere, are directed along the lines of magnetic force, the elevation of the tops of the streamers can be computed. From the photograph in Figure 4, Wesöe found that the tops were between 177 and 288 kilometers. The latter altitude represents the greatest altitude for the top of streamers which could be derived from the photographs of the *Maud* Expedition. This maximum altitude is small as compared with those observed by Störmer in more southerly latitudes but agrees well with those found close to the zone of maximum frequency. By means of a number of photographs of streamers from one station it should be possible to determine with considerable accuracy the greatest altitude to which the streamers reach.

The radiation-point of a corona can frequently be determined with fair accuracy by means of visual observations but a photograph which can be examined closely will give much more reliable results. Symmetrically developed coronæ are seldom seen in the vicinity in the zone of maximum frequency but forms consisting of bands across the sky and streamers forming half a corona are not unusual. Figure 5 shows a corona of this type which was photographed on March 11, 1924, at $23^h\,12^m$ local mean time in 75° 12′ north latitude and 158° 45′ east longitude. From this picture Wesöe found that the altitude and azimuth of the radiation-point were 82°.3 and 5°.0 east, respectively, while the corresponding values for the magnetic zenith were 82°.6 and 2°.3 east.

The interest in auroral research has been steadily increasing for a number of years and a committee of the International Geodetic and Geophysical Union is at present preparing an auroral atlas and instructions for photographic and visual observations of the aurora. Considering this it seems pertinent to draw attention to some problems, the study of which can be advanced from photographs from one station, especially since it is possible to point out the valuable results which Wesöe has derived from the few photographs which were taken on the *Maud* Expedition.

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[5] Sverdrup, H. U.: Magnetic, atmospheric-electric and auroral results, *Maud* Expedition, 1918-1925. *Res. Dep. Terr. Mag.*, v. VI, pp. 309-524. Washington, 1927.

THE MAGNETIC CHARACTER OF THE YEAR 1927 AND REVIEW OF THE YEARS 1917-1927

By G. van Dijk

The annual review of the "Caractère magnétique de chaque jour" for 1927 has been drawn up in the same manner as the preceding years[1]; moreover it contains a review of the collaboration of the observatories during the years 1917-1927.

In 1927, 43 observatories contributed to the quarterly reviews; 41 of them sent complete data. Table II of the annual review, containing the mean character of each day and each month, the lists of calm days and of disturbed days and the days, recommended for reproduction, are reprinted here. (It will be recalled that at the meeting of the Commission for Terrestrial Magnetism and Atmospheric Electricity of the International Meteorological Committee at Zürich, September 17, 1926, it was agreed that certain days included amongst the five most disturbed days of the month, should not be included amongst the days selected for the calculation of the diurnal irregularities. Days of character 2.0 should be excluded and other highly disturbed days, on which loss of trace has occurred.)

From the review of the years 1917-1927 it is seen that altogether 53 observatories have contributed to the "Caractère magnétique"; an observatory, that has been removed, is taken with the new one as one station (Greenwich-Abinger, Vieques-San Juan, Melbourne-Toolangi).

In a graphical representation the times, for which the observatories sent character-lists, have been indicated by straight lines; if the data have not been made use of in preparing the annual review, the lists having been received too late or being incomplete, the lines have been drawn thinner. In the years 1917-1927, successively 39, 38, 40, 39, 40, 43, 42, 43, 42, 43, and 43 stations have contributed; 35, 34, 37, 36, 38, 37, 38, 40, 39, 43, and 41 of them sent complete data, which have been made use of in preparing the annual reviews.

The data of 22 observatories have been employed for all the years 1917-1927, namely: Sitka, Rude Skov, Eskdalemuir, Meanook, Stonyhurst, Seddin, De Bilt, Greenwich-Abinger, Val Joyeux, Agincourt, Tortosa, Coimbra, Cheltenham, San Fernando, Tucson, Dehra Dun, Honolulu, Bombay, Antipolo, Buitenzorg, Apia, and Pilar; 10 among them, namely, Sitka, Stonyhurst, Seddin, De Bilt, Greenwich, Val Joyeux, Cheltenham, Honolulu, Bombay, and Buitenzorg also sent complete data for the preceding eleven-year period, 1906-1916.

[1]*Terr. Mag.*, v. 32, 1927 (64).

Table showing magnetic character for each day of the year 1927

Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Mean
January	1.3	0.7	0.1	1.5	1.0	0.8	1.9	1.1	0.1	0.1	0.8	0.8	0.5	0.7	0.3	0.2	0.6	0.6	0.8	0.1	0.0	0.0	0.1	1.1	1.1	1.1	0.3	0.2	0.6	0.3	0.1	0.62
February	0.4	0.2	0.9	0.4	0.4	0.0	0.0	0.8	1.5	1.2	0.5	1.0	1.1	0.6	0.4	1.1	0.7	0.9	0.7	0.4	0.1	0.0	0.0	1.4	1.1	1.0	0.6	1.1				0.66
March	1.2	0.3	0.4	0.2	0.5	0.6	0.5	0.7	1.4	1.3	0.8	0.5	0.8	0.8	1.1	1.8	1.6	1.1	0.9	1.0	0.2	0.1	0.1	0.0	0.1	1.3	1.7	1.6	0.9	0.8	0.6	0.80
April	0.5	0.5	0.3	1.0	0.7	0.2	0.9	0.9	1.4	0.8	1.5	1.0	0.9	1.9	0.9	0.1	0.0	0.1	0.1	0.1	0.0	0.0	0.9	1.2	0.9	0.2	0.1	0.0	0.3	0.5		0.60
May	0.4	0.5	1.3	1.0	1.8	0.6	1.6	1.0	0.9	0.3	0.0	0.0	0.3	0.5	1.2	0.9	0.1	0.1	1.0	1.4	0.6	0.4	0.3	0.2	0.3	0.1	1.0	1.2	0.4	0.2	0.2	0.65
June	0.9	1.0	0.6	0.3	1.1	0.6	0.3	0.0	0.1	0.7	1.0	1.0	0.3	0.5	0.6	0.2	0.6	0.1	0.0	0.0	0.1	0.3	0.2	0.0	0.1	1.3	0.7	0.3	0.3	0.7		0.47
July	1.0	0.6	0.1	0.2	0.6	0.7	1.0	0.9	0.1	0.0	0.2	0.2	0.3	0.2	0.1	0.1	0.9	0.2	0.7	0.7	1.6	2.0	1.1	0.8	0.4	0.7	0.8	0.2	0.1	0.3	0.3	0.56
August	0.7	1.0	0.9	0.8	0.8	0.1	0.2	0.3	0.2	0.2	0.3	0.2	0.0	0.4	0.8	0.7	0.2	0.2	0.9	2.0	2.0	0.8	0.5	0.2	0.0	0.0	0.3	0.2	1.5	1.5	0.9	0.61
September	1.2	0.5	0.6	1.4	0.9	1.2	1.2	1.2	1.4	1.6	1.0	0.5	0.9	1.0	0.8	0.2	0.2	0.2	0.2	0.7	0.4	0.1	0.0	0.1	1.0	1.0	0.8	0.7	1.0	0.9		0.77
October	0.3	0.9	0.8	0.1	0.9	1.0	1.5	1.3	1.0	1.8	0.9	2.0	1.7	0.7	0.4	0.3	0.1	0.3	0.5	0.5	0.1	2.0	1.9	1.0	0.8	0.9	0.3	0.3	0.7	0.8	0.1	0.84
November	0.0	0.0	0.1	0.5	0.2	0.1	0.0	0.6	0.4	0.2	0.2	0.2	0.5	0.0	0.0	0.4	0.2	1.5	0.8	0.7	0.8	0.1	0.0	0.4	0.0	0.3	0.5	0.1	0.8	0.9		0.35
December	0.8	0.9	0.2	0.0	0.9	1.0	0.7	0.7	0.7	0.6	0.1	0.3	1.7	1.4	1.2	0.7	1.3	1.2	1.1	0.0	0.0	0.1	0.5	0.1	0.1	0.3	0.1	1.3	0.5	0.1	0.8	0.63

Table showing magnetically calm and most disturbed days for the year 1927

Month	Calm Days						Most Disturbed Days				
January	(0.06)	9,	10,	21,	22,	23.	**1** (1.3),	**4** (1.5),	**7** (1.9),	**24** (1.1),	**25** (1.1).
February	(0.02)	6,	7,	21,	22,	23.	**9** (1.5),	**10** (1.2),	**24** (1.4),	**25** (1.1),	**28** (1.1).
March	(0.11)	2,	22,	23,	24,	25.	**9** (1.4),	**16** (1.8),	**17** (1.6),	**27** (1.7),	**28** (1.6).
April	(0.06)	17,	18,	20,	21,	22.	**9** (1.4),	**11** (1.5),	**12** (1.0),	**14** (1.9),	**24** (1.2).
May	(0.08)	11,	12,	17,	18,	26.	**3** (1.3),	**5** (1.8),	**7** (1.6),	**20** (1.4),	**28** (1.2).
June	(0.04)	8,	19,	20,	21,	24.	**2** (1.0),	**5** (1.1),	**11** (1.0),	**12** (1.0),	**26** (1.3).
July	(0.09)	3,	10,	15,	16,	29.	**1** (1.0),	**7** (1.0),	**21** (1.6),	**22** (2.0),	**23** (1.1).
August	(0.09)	6,	7,	13,	25,	26.	**19** (0.9),	**20** (2.0),	**21** (2.0),	**29** (1.5),	**30** (1.5).
September	(0.13)	16,	17,	22,	23,	24.	**4** (1.4),	**6** (1.2),	**7** (1.2),	**9** (1.4).	**10** (1.6).
October	(0.13)	1,	4,	17,	21,	31.	**10** (1.8),	**12** (2.0),	**13** (1.7),	**22** (2.0),	**23** (1.9).
November	(0.03)	2,	7,	14,	22,	25.	**18** (1.5),	**19** (0.8),	**21** (0.8),	**29** (0.8),	**30** (0.9).
December	(0.05)	4,	20,	21,	24,	27.	**13** (1.7),	**14** (1.4),	**17** (1.3),	**18** (1.2),	**28** (1.3).

Days recommended for reproduction

First selection: April 14; July 22; October 12. Second selection: January 7; March 27; May 5; August 21; October 22.

THE DIURNAL VARIATION OF THE NORMAL EARTH-CURRENT IN NORTHERN SWEDEN

By David Stenquist

During August, 1924, to July, 1927, measurements [1] of earth-currents were made in southern Sweden at the telegraph-office of Lund (latitude 55° 42′ north, longitude 13° 11′ east). During 1924 to 1928 similar measurements were made also in northern Sweden at the telegraph-offices of Luleå and Haparanda and at the telephone-offices of Matarengi (Övertorneå) and Jokkmokk. The north latitudes and east longitudes of these four places are: Jokkmokk, 66° 35′ and 19° 51′; Matarengi, 66° 21′ and 23° 37′; Haparanda, 65° 50′ and 24° 08′; Luleå, 65° 35′ and 22° 10′.

In arranging the lines and in making the measurements I have had the great help of C. G. Wahlberg, Chief Engineer; H. Reine, Telegraph-commissary; and G. Lidén, Telegraph-commissary. My wife has assisted me in the time-consuming calculations. The measurements at Haparanda, here published, were made during July 1927 to June 1928. Because this series of observations is longer than those of Jokkmokk, Matarengi, and Lulea, it is described first. At the telegraph-office of Haparanda there was a recording instrument for each of the two lines. One line is in a northerly direction from Haparanda to Tanos, the other line is in a westerly direction from Haparanda to Palovaara. The length of the Tanos-line was 3.1 kilometers and of the Palovaara-line, 3.3 kilometers. Haparanda is 90 kilometers from electric tram and it is believed that no disturbing effect from industrial currents existed during the observations.

The two recording instruments were by D. Horn of Leipzig. One scale-division on the instruments is equivalent to 1/20 milliampere and since the length of each division is 1.6mm, 1/200 milliampere can be read. The strips of recording paper move 12 cm per hour and one strip suffices for a week. The intensity of the current is scaled for every fifteen minutes and hourly mean taken for each week. The departure of the hourly means from the mean of day is calculated and expressed in milliamperes as $\triangle i_T$ and $\triangle i_P$, which are reckoned positive for current flowing from Haparanda to Tanos and from Palovaara to Haparanda, respectively. When the current varies greatly, the corresponding hourly value is omitted; this occurred on 19 days.

[1]See *Terr. Mag.*, v. 32, 1927 (143-145).

The lines are bare conductor suspended from wooden poles with porcelain insulators. The insulation-resistance of either line was never less than one megohm per kilometer. At Haparanda the water pipes, which are below the frost-line, were used as earth-plates. At Tanos and at Palovaara coils of iron wire similar to that of the lines were used as earth-plates and these were buried in the ground below the frost-line. The resistances of the circuits are determined once each week. The resistance of a line is divided by the length of the line and designated r_T for the Tanos-line and r_P for the Palovaara-line. The earth-current potential-gradients in the direction of the lines are calculated in mv/km by the formulas

$$\triangle V_T = r_T \,.\, \triangle i_T \quad \text{and} \quad \triangle V_P = r_P \,.\, \triangle i_P$$

The direction of the line from Haparanda to Tanos is 23° west of north and that from Haparanda to Palovaara 104° west of north. The potential gradients in the direction of geographical north, $\triangle N$, and east, $\triangle E$ ($\triangle N$ being taken positive, when it is such as to produce a current flowing from south to north and $\triangle E$ positive, when it is such as to produce a current flowing from west to east), can be calculated by the formulas

$$\triangle N = (\sin 23°/\sin 99°)\ \triangle V_P + (\sin 76°/\sin 99°)\ \triangle V_T$$
$$\triangle E = (\cos 23°/\sin 99°)\ \triangle V_P - (\cos 76°/\sin 99°)\ \triangle V_T$$

Tables 1 and 2 contain the mean hourly departures by months for July 1927 to June 1928. One finds for the diurnal variation of normal earth-current:

(1) At Haparanda the current is roughly of equal intensity during the day and during the night. At Lund the current is also roughly of equal intensity during the day and during the night. The day-current at Haparanda and Lund is not predominant as at more southerly latitudes.

(2) At Haparanda the current is stronger during the winter than during other seasons. At Lund the current is roughly of equal intensity during winter and other seasons. At more southerly latitudes the current is weaker during winter than during other seasons.

(3) At Haparanda the northward component (5.2 mv/km) is weaker than the eastward component (12.7 mv/km). At Lund the northward component (0.6 mv/km) and the eastward component (0.5 mv/km) are roughly of equal intensity. At more southerly latitudes the northward component is stronger than the eastward component.

(4) At Haparanda and at Tortosa (latitude 41° north) the current is much stronger than at Lund.

TABLE 1—*Diurnal variation of northward earth-current component* (ΔN) *in millivolts per kilometer at Haparanda, Sweden, July 1927 to June 1928*

Middle European Time	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Year
h h													
0− 1	+ 6.1	+7.0	0	+1.5	+ 3.7	+ 5.3	+ 1.8	+2.4	− 1.9	+6.7	+3.9	+2.8	+3.3
1− 2	+ 6.5	+8.1	+3.4	+5.9	+ 2.3	+ 4.9	+ 3.7	+2.9	− 3.5	+4.0	+2.7	+4.6	+3.8
2− 3	+ 5.9	+7.5	+4.1	+4.6	+ 4.9	+10.4	+ 4.8	+1.2	+ 1.8	+3.5	+1.1	+5.3	+4.6
3− 4	+ 9.3	+7.7	+5.6	+5.8	+ 7.5	+ 7.9	+ 5.6	+1.9	+ 0.3	+3.8	+1.1	+4.3	+5.0
4− 5	+11.6	+7.3	+6.8	+5.6	+ 7.8	+11.8	+ 5.1	+1.2	− 0.1	+2.6	+1.4	+4.3	+5.4
5− 6	+ 7.8	+7.9	+7.0	+7.2	+ 9.5	+ 9.7	+ 3.6	+2.7	− 0.5	+3.8	+1.5	+4.7	+5.4
6− 7	+ 6.5	+8.0	+5.8	+2.1	+ 8.9	+10.2	+ 3.1	+0.8	− 1.0	+0.5	−3.7	+1.3	+3.5
7− 8	+ 0.9	−1.5	+2.3	+0.6	+ 4.6	+ 2.5	+ 3.7	−0.1	− 1.7	−5.0	−2.0	+2.2	+0.5
8− 9	+ 6.0	+2.7	+0.5	−3.4	− 2.6	− 7.7	− 2.5	−2.1	− 9.8	−3.6	−4.1	+2.3	−2.0
9−10	+ 1.1	−3.5	−4.2	−5.6	− 5.2	− 4.8	− 2.0	−5.9	− 7.6	−6.5	−4.8	+0.9	−4.0
10−11	+ 3.3	−4.6	−0.8	−3.9	− 8.6	+10.6	− 3.5	−3.8	− 6.8	−3.8	−6.8	−0.3	−2.4
11−12	− 0.5	−2.9	+0.2	−2.7	−10.2	+ 7.3	− 1.1	−2.3	+ 0.3	−3.5	−0.4	+1.1	−1.2
12−13	+ 4.2	−1.4	−0.4	−2.1	− 9.9	+ 0.2	− 0.3	−0.8	+ 1.6	−3.9	−2.6	+0.4	−1.2
13−14	+ 2.3	−6.5	−2.6	−2.5	− 6.6	+ 2.9	− 2.3	−9.2	−12.1	−7.1	−8.2	−4.6	−3.9
14−15	+ 0.2	−3.6	−0.9	−4.0	− 6.2	+ 2.1	+ 1.0	−2.3	+ 5.1	−8.1	−7.0	−5.0	−2.4
15−16	− 4.9	−2.2	+2.4	+1.6	− 7.6	+ 1.6	− 3.5	+3.0	+13.5	−3.7	−1.9	−9.5	−0.9
16−17	−11.5	+0.1	+6.6	+4.4	− 5.4	−10.3	− 8.9	+0.1	+14.4	+1.9	+2.6	−6.8	−1.1
17−18	−13.0	−3.6	+0.2	−0.4	− 2.9	− 8.6	− 9.0	−1.7	+14.2	+2.4	+1.6	−5.0	−2.1
18−19	−10.9	−4.2	−3.8	−4.3	− 0.2	−17.2	− 4.1	−2.0	+ 8.2	−0.3	−0.9	−2.7	−3.5
19−20	− 9.3	−6.5	−9.0	−2.4	+ 0.7	−18.8	− 8.3	−0.2	+ 4.0	+5.3	+5.6	+1.5	−3.1
20−21	− 9.4	−5.5	−9.7	−5.8	+ 3.2	− 4.1	− 0.5	+2.3	− 3.3	+4.4	+4.3	−1.5	−2.1
21−22	− 5.0	−3.4	−7.0	−5.3	+ 4.3	− 5.9	+ 1.1	−0.3	− 1.6	+3.3	+1.3	−0.5	−1.6
22−23	− 3.9	−2.0	−4.7	−0.5	+ 1.7	− 5.0	+10.8	+5.8	− 2.2	+4.5	+4.0	+0.3	+0.7
23−24	+ 1.5	−4.5	−2.3	+0.1	+ 2.1	− 3.0	+ 3.7	+4.6	+ 1.8	+5.8	+3.8	+1.4	+1.2
Average departure from mean	6.0	4.7	3.8	3.5	5.3	5.4	3.9	2.5	4.9	4.1	3.2	3.1	5.2

During September to November 1924 measurements of earth-currents were made at Luleå (Etude des courants telluriques Memoires publiés par la Direction des Télégraphes de Swède, Stockholm, 1925)[2]. Cr. C. Chree has been so kind as to inform me in a letter of some miscalculations in the values for Luleå. Table 3 contains the recalculated figures. It is possible, that the perturba-

TABLE 3—*Diurnal variation in earth-currents in millivolts per kilometer at Luleå, Sweden, September to November 1924*

Component	Middle European time in hours											
	12−2	2−4	4−6	6−8	8−10	10−12	12−14	14−16	16−18	18−20	20−22	22−24
ΔN	+11.8	− 0.3	+2.0	− 5.9	+3.0	−0.6	−1.3	−11.8	−8.1	−2.7	+ 3.2	+10.9
ΔE	− 6.3	+12.2	+6.9	+14.8	+4.2	+3.5	+3.0	+12.2	−1.7	−6.2	−13.4	−28.3

[2]The last three lines of the first paragraph of page 143 of my article in *Terr. Mag.*, v. 32, 1927, should be corrected to read "Because of a miscalculation these Lund-values are ten times too great."

Table 2—*Diurnal variation of eastward earth-current component* (ΔE) *in millivolts per kilometer at Haparanda, Sweden, July 1927 to June 1928*

Middle European Time	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Yea
h h													
0− 1	−18.6	−10.1	− 8.7	−3.8	−4.6	− 4.4	−10.8	− 4.7	− 6.8	− 8.6	− 5.8	− 6.4	− 7
1− 2	−23.9	−19.7	−11.5	−6.1	−5.2	− 5.9	−15.9	− 4.6	− 7.4	− 5.5	− 4.8	− 8.5	− 9
2− 3	−30.3	−21.3	−15.1	−8.0	−7.8	− 7.7	−13.5	− 5.0	− 5.4	− 8.9	− 5.1	−11.1	−11
3− 4	−24.5	−23.4	−16.2	−8.7	−8.8	− 7.4	−14.4	− 5.0	− 6.1	− 9.2	− 5.5	−12.8	−11
4− 5	−31.6	−25.5	−15.4	−7.3	−7.2	− 8.9	−13.6	− 5.9	− 5.0	−10.8	− 6.3	−14.9	−12
5− 6	−32.2	−27.5	−18.1	−5.6	−5.4	− 8.4	−13.5	− 6.2	− 5.4	−12.2	− 9.4	−13.9	−13
6− 7	−32.9	−27.0	−16.3	−3.9	−5.0	−10.0	−12.1	− 5.9	− 5.5	− 5.0	−10.6	−17.2	−12
7− 8	−19.1	−15.6	− 7.8	−0.5	−1.1	−15.6	−11.1	− 4.6	− 3.7	− 1.2	− 7.5	−12.9	− 8
8− 9	−14.3	− 8.9	− 3.3	+1.1	+0.5	−15.4	− 9.1	+ 4.6	+ 2.8	− 2.1	− 1.3	− 8.2	− 4
9−10	− 1.2	−11.3	− 2.3	+0.8	+0.8	− 5.7	− 8.1	+ 5.5	+ 3.3	+ 1.6	− 3.9	− 2.1	− 1
10−11	−11.3	−13.8	− 6.8	−0.4	+1.2	+ 5.4	−12.4	+ 4.0	+ 1.0	− 1.3	− 6.6	−10.5	− 4
11−12	−16.8	−13.7	− 3.0	+0.1	+2.7	+12.2	−13.1	+ 5.0	+ 9.6	− 1.5	− 1.7	−12.6	− 2
12−13	−20.2	−10.2	− 6.7	+2.6	+4.6	+19.5	− 8.4	+ 5.6	+15.5	− 2.8	− 5.9	− 8.8	− 1
13−14	+ 1.0	− 0.5	− 2.3	+4.4	+5.6	+24.2	−10.2	+10.5	+16.5	+ 5.7	+ 2.5	+ 0.6	+ 4
14−15	+29.7	− 2.2	− 1.2	+6.2	+7.2	+18.9	+ 0.3	+ 0.9	+ 8.7	+ 6.7	+ 9.5	+17.4	+ 8
15−16	+46.1	+ 9.0	− 0.1	+3.6	+6.4	+27.5	+14.4	+10.9	+ 4.1	+10.8	+14.5	+24.6	+14
16−17	+52.3	+35.6	+ 8.4	+3.3	+5.4	+25.3	+26.3	+ 3.0	+ 5.8	+10.4	+14.0	+24.7	+17
17−18	+48.1	+53.4	+15.6	+4.8	+5.9	+16.1	+18.2	− 0.9	+ 8.9	+19.7	+ 8.5	+24.8	+18
18−19	+35.8	+44.2	+19.9	−2.7	+3.6	−19.9	+35.5	+ 0.5	+ 7.8	+11.2	+ 9.5	+18.3	+13
19−20	+26.1	+29.0	+24.6	+0.2	−0.5	−21.9	+26.3	+ 0.2	+ 3.6	+ 9.7	+ 3.2	+12.3	+ 9
20−21	+20.3	+30.8	+27.8	+2.9	−0.5	−20.7	+27.1	+ 2.1	− 8.1	+ 5.9	+11.4	+10.5	+ 8
21−22	+15.9	+20.2	+23.3	+4.2	+0.8	−11.6	+ 8.4	+ 0.5	−12.3	+ 3.9	+ 6.2	+ 6.4	+ 5
22−23	+ 8.3	+ 5.6	+13.8	+3.3	+1.1	+ 1.0	+ 5.4	− 3.2	−13.1	− 1.1	− 0.5	+ 2.7	+ 1
23−24	+ 3.7	− 2.0	+ 3.0	+1.7	−0.4	+ 3.3	+ 8.6	− 8.4	− 9.6	− 5.4	− 4.3	+ 0.3	− 0
Average departure from mean	23.7	19.3	11.4	3.6	3.9	13.3	14.2	4.5	7.4	6.8	6.6	11.8	12

tions from the electric railway Luleå to Narvik has affected the values at Lulea in spite of the attempt to eliminate them.

In the year 1925 measurements of earth-current were made at Matarengi during the months June to November and at Jokkmokk during the months June to August. The length of the lines used

Table 4—*Diurnal variation in earth-currents in millivolts per killometer at Matarengi and Jokkmokk, Sweden, June to December and June to August* 1925, *respectively*

Com-po-nent	Middle European time in hours											
	12−2	2−4	4−6	6−8	8−10	10−12	12−14	14−16	16−18	18−20	20−22	22−24
ΔV_M	+ 5.4	+ 7.0	+ 4.0	+1.4	− 2.0	− 4.8	− 5.6	− 2.2	−1.8	−2.0	−3.0	+ 4.0
ΔV_J	−26.2	−26.0	−10.7	−6.0	+28.2	+26.5	+22.5	+16.2	+7.0	+4.2	−6.2	−21.2

were two kilometers each. The direction of the Matarengi-line was approximately north to south, following the Hietaniemi Road. The direction of the Jokkmokk-line was approximately east to west, following the Junkarhällan Road. The earth-plates were below the

frost-line. The recording instruments were supplied by Dr. Horn of Leipzig. The shortest distance to an electric tram is 97 kilometers at Matarengi and 49 kilometers at Jokkmokk. When the current varied greatly the value for the hours concerned is omitted. The earth-current gradients in the directions of the lines are calculated and expressed in millivolts per kilometer as $\triangle V_M$ and $\triangle V_J$ ($\triangle V_M$ being taken positive, when it is such as to produce a current flowing approximately from south to north and $\triangle V_J$ positive, when it is such as to produce a current flowing approximately from west to east). Table 4 contains the results. The values for Luleå, Matarengi, and Jokkmokk are in rather good accord with those for Haparanda.

Stockholm Telegrafverkets Provningsanstalt

REVIEWS AND ABSTRACTS

(See also pages 187 and 261)

Dauzère, C., et J. Bouget: *Influence de la constitution géologique du sol sur les points de chute de la foudre.* (Paris, C.-R. Acad. sci., T. 186, No. 23, 1928, pp. 1565-1566); *Sur l'ionisation intense de l'air dans les lieux fréquemment foudroyés* (*Ibidem*, No. 25, pp. 1744-1746).

In the first of these papers the authors have reported upon investigations of the geological and other conditions under which considerable damage was caused to property by direct lightning-strokes. Their attention was especially directed to cases (*a*) where one would not expect, in accordance with current ideas, that the natural conditions would be conducive to the occurrence of such catastrophes, and (*b*) places which have been struck by lightning on more than one occasion. Among the principal conclusions based on their work are the following: (1) Lightning strikes preferably certain places which are not necessarily prominent points in the relief of the soil; (2) the location of the points frequently struck bears a relation to the geological structure of the soil, compact limestones enjoying a high degree of security while silicate rocks and soils containing metallic ores are frequently struck by lightning; (3) points situated along lines of contact of two geologically different terrains are often the most exposed to lightning, such lines of contact offering a minimum resistance to erosion and thus causing certain passes and depressions formed along their course to be particularly dangerous.

The authors believe that the preceding phenomena may be given two explanations which are not necessarily contradictory: (*a*) Points struck by lightning are those where the soil has an electrical conductivity greater than that of the surrounding points; (*b*) lightning follows, in the air, the path of least resistance, that is, of greatest ionization.

It is stated that the first of these explanations is in good agreement with the facts determined by their investigations of cases of damage caused by lightning to a hydroelectric plant and the transmission-lines of an electric railway. In

order to test the admissibility of the second explanation, the authors made certain experiments for the purpose of comparing the values of the ionization of the air in the immediate neighborhood of a point where the lightning has struck and at points a hundred meters distant in various directions. These experiments are described and their results given in the second paper under review. The observations were made with the classical Elster and Geitel apparatus at a distance of 15 cm above the ground. It is stated that although the results varied greatly with the meteorological conditions, nevertheless by making the interval between observations at neighboring places as brief as possible, results could be obtained which were sufficiently comparable. The results of a typical set of observations are given which show for negative ions: (*a*) At a point 200 meters southeast of the point struck, 0.90×10^{-4} E.S.U.; (*b*) at a point struck, 1.24×10^{-4} E.S.U.; (*c*) at a point 200 meters northwest of the point struck, 0.87×10^{-4} E.S.U. The meteorological conditions did not change during these observations although a rainstorm began immediately after the last observation.

Similar observations were made in a large number of places with results analogous to those of the example cited above. The conclusions briefly stated are: (1) There exists places in which the ionization of the air near the soil is constantly more intense than that observed in neighboring places at the same altitude and under the same physical conditions; (2) the places frequently struck by lightning coincide with the places of maximum ionization and the location of both depends on the geological constitution of the soil.

Confirmation of these results by experiments made in other localities would be of much value in the furtherance of this interesting question.

S. J. Mauchly

Rosé, N.: *Problemy izuchenia zemnogo magnetizma na territorii Iakutii* (*Problèmes de l'étude du magnétisme terrestre en Iakoutie*). Matériaux de la Commission pour l'étude de la République ASS Iakoute. Leningrad, Acad. Sci., 1928, Livr. 11, pp. 183-195.

The present paper is a consideration of all existing magnetic observations made on the territory of the Siberian Soviet Republic of Yakutia. These observations extending from 1736 to 1921 embrace 250 different stations, but at only 72 have all three elements been determined. The distribution of stations is far from ideal, the greater part being concentrated along the Lena River and the northern littoral. Moreover, the observations are separated by unequal intervals of time.

Repeat-observations of magnetic declination obtained at 35 stations have served for an approximate determination of the secular change on the basis of which a table has been worked out giving in geographical degrees, the differences in declination for the epochs 1830, 1850, 1870, 1880, 1890, 1900, and 1920 from that for 1925. From the values of the declination-determinations reduced to the epoch 1925, an isogonic chart accompanying the article has been constructed.

While, as the author concludes, the magnetic data at present available for Yakutia do not suffice for the solution of the two fundamental problems of a magnetic survey—the investigation of a detailed geographical distribution of the magnetic elements and a study of their secular changes—yet for the general theoretical considerations of the Earth's magnetism such studies as this are of great value and it is to be hoped that it may lead to more detailed survey-operations in the remote regions of Siberia. H. D. Harradon

EINIGE WICHTIGE PLANETARE URSACHEN FÜR DIE SCHWANKUNGEN DER SONNENTÄTIGKEIT UND DES ERDMAGNETISMUS IM JAHRE 1926

Von Franz Göschl

Im Augustheft 1927 der *Annalen der Hydrographie* behandelte ich „Kosmische Einflüsse auf die erdmagnetischen Schwankungen" und in einem Aufsatze des Jahrganges 1928 derselben Zeitschrift „Die Einwirkung der äussersten Planeten auf die Sonnenflecken." Von der erstgenannten Abhandlung erschien ein Referat im Aprilheft 1928 der *Meteorologischen Zeitschrift* mit einer Anwendung auf die Erläuterung des erdmagnetischen Charakters 1926, die durch eine Tabelle veranschaulicht wurde. Hier möge mittels eines Diagrammes der Ablauf der magnetischen Schwankungszahlen des gleichen Jahrganges aus den im erstgenannten Aufsatze dargelegten Gesetzmässigkeiten erklärt werden. Da aber als primäre Erscheinung doch sicher die Einwirkung der Planeten auf die Sonnentätigkeit anzusehen ist, soll zuvor im ersten Teil in wenigen Strichen eine Tabelle die wichtigsten derartigen Beziehungen veranschaulichen.

I. Wie in dem oben an 2. Stelle genannten Aufsatze näher durchgeführt ist, werden bei den Durchgängen der innerhalb des Asteroidengürtels ziehenden Planeten, Mars, Erde, Venus, und Merkur, zwischen Jupiter und Sonne Meteoriten zugelenkt, welche bezüglich Merkur sofort bzw. in ein paar Tagen, von Seiten der Venus und der Erde aber mitunter erst im Laufe der nächsten 2 Monate von der Sonne abgefangen werden, wo sie durch ihren Aufsturz die in den Sonnenflecken zu Tage tretenden Wirbel erregen. Die beigelegte Tabelle, welche in der 3. Spalte unter *R* die Relativzahlen des beobachteten Fleckenareale enthält, führt in der 1. Spalte unter *E* d. i. Einstrahlungsursachen diese Durchgänge als von der Sonne aus gerechnete Konjunktionen an, also den Merkurdurchgang durch *McJ*, den Venusdurchgang durch *VcJ*, Erddurchgang *EcJ*, und Marsdurchgang *AoJ*. Bezüglich der Raschheit der Einwirkung auf die Sonne kommt es auf die Stellung der vier genannten Planeten *untereinander* an. Die Meteoritenzulenkung zur Sonne wird ergiebiger, wenn nur ein vereinzelter (*isolierter*) Durchgang eines solchen zwischen Jupiter und Sonne stattfindet, weil dann das Zentralgestirn ungehindert die näher gezogenen Meteoriten abfangen kann. Wenn hingegen eine *Doppelkonjunktion* zu Jupiter stattfindet, vielleicht gar von Venus und Erde, dann werden die zwar stärker als bei einer Einzel-Jupiterkonjunktion zugelenkten Meteoriten vorläufig noch in der Nähe der inneren Planeten festgehalten. Hiebei werden die Meteoriteneinstürze auf diese beiden Planeten (in Unwetterkatastrophen) sich häufen während für die Sonne nur wenig übrig bleibt. Auf ihr zeigen sich wegen der seltenen Aufstürze nur gelegentliche, kurze Anstösse zur Fleckenbildung; im allgemeinen muss ihre Tätigkeit

wegen des Zurückhaltens der Meteoriten zur Ruhe gelangen. Die in der Nähe von Venus and Erde (bzw. der sonstigen inneren, in Doppelkonjunktion zu Jupiter tretenden Planeten) weilenden Meteoriten können jedoch bei völliger Trennung der beiden am ehesten abgefangen werden, also bei ihrer von der Sonne aus gerechneten Opposition. Es soll daher die Opposition als *Auslösungsfaktor* bezeichnet werden, weil die bei den Jupiterkonjunktionen erzielten Meteoritenzulenkungen hiebei zur vollen Entfaltung für die Sonne gelangen. Wenn einer dieser Planeten bereits in der Zwischenzeit in Sonnennähe gerät, ist natürlich daselbst die günstige Gelegenheit für ein Abfangen der Meteoriten seitens der Sonne gegeben, weshalb auch das Perihel als Auslösungsfaktor angesprochen wird.

Aus der Hypothese, dass isolierte Konjunktionen der inneren Planeten zu Jupiter die hervorstechendsten Maxima erregen, hingegen Doppelkonjunktionen einen Wechsel von Hemmung und Kräftigung der Sonnentätigkeit verursachen, ergibt sich sofort die Vorbedingung für ein deutliches Minimum, nämlich diese Konjunktionen der inneren Planeten zueinander. Besonders einschneidend muss das Minimum sich gestalten, wenn *drei* solcher innerer Planeten in einer vom Leitstrahl zu Jupiter verschiedenen Richtung in Konjunktion geraten. Wenn auch einige Nachzügler von Meteoriten stets die inneren Planeten begleiten, die dann die Sonne bei Perihelien und sonstigen Anlässen sich als Beute erobert, so muss doch dieses Wegfangen bedeutend erschwert werden, wenn die Anziehungskraft der in Konjunktion stehenden drei Planeten sie in deren Nähe zurückhält. Mangels an erregenden Meteoriteneinstürzen muss daher die Sonnentätigkeit abflauen. Bezüglich des Stärkegrades dürften die Konjunktionen in folgende Reihe zu stellen sein: Venus-Erde als bedeutsamste, dann abnehmend Venus-Merkur, Venus-Mars oder Erde-Merkur und schliesslich die übrigen Marsbegegnungen. Besonders deutlich wird die Hemmung, wenn Erde, Venus, und Merkur in einer Richtung stehen. Aus der Annahme, dass einige kosmische Massen von den inneren Planeten mitgezogen werden, würde sich ergeben, dass bei ihren gegenseitigen Oppositionen—auch unabhängig vom Jupiter-Leitstrahl—einige Mitläufer dabei vom Zentralgestirn weggezogen werden. Es sind daher bezüglich *sekundärer Anschwellungen* der Sonnentätigkeit den Oppositionen in derselben Reihenfolge die Gewichte beizulegen wie bezüglich der hemmenden Konjunktionen.

Nach der vorgelegten Hypothese hat man Einstrahlungsursachen, Auslösungsfaktoren, und Hemmungen voneinander zu unterscheiden. In der beigelegten Tabelle registriert die erste Spalte, wie schon erwähnt, die Einstrahlungsursachen. Die zweite zeigt unter *A* als Auslösungsfaktoren an: (1) die gegenseitigen Oppositionen der inneren durch die folgenden gewählten Zeichen, z. B., die Venus-Merkur-Gegenstellung durch *MoV;* (2) die Perihelien durch ein beigefügtes *P*, z. B., Venus-Perihel durch *VP;* (3) die Oppositionen von Venus and Erde zu Jupiter, angemerkt durch *EoJ;* (4) die Quadratur der Venus zur Erde,

VqE. Die 4. Spalte verzeichnet unter *II* als Hemmungsursachen die Konjunktionen der inneren Planeten untereinander. Aus den genannten Gesichtspunkten lassen sich die Maxima und Minima der Sonnentätigkeit innerhalb eines Jahres erklären.

Anmerkung—Wenn man nach diesen Regeln einen bestimmten Jahrgang untersucht, empfiehlt es sich, von der gegenseitigen Lage der wichtigsten inneren Planeten (Venus und Erde) auszugehen, also zunächst auf ihre Konjunktion bzw. Opposition zu achten, was geozentrisch mit der unteren bzw. oberen Venus-Sonnenkonjunktion zusammenfällt. Der günstigste Fall wäre nun der, dass bei einer Venus-Erdeopposition die Konjunktion des einen (z. B. der Venus) zu Jupiter auftritt, weil dann auch die Opposition des anderen zum Hauptplaneten sich anschliessen muss. Es fallen dann Zulenkung und Auslösung nahe zusammen. An allen drei Terminen (Venus-Erdeopposition, Venus-Jupiterkonjunktion, und Erde-Jupiteropposition) zeigen sich dann erfahrungsgemäss Höchstwerte der Sonnentätigkeit. Wenn aber die Venus-Erdekonjunktion auftritt, dann bedeutet sie an sich nach obigem einen starken Hemmungsfaktor. Immerhin können sich an sie zwei Fälle stärkerer Zustrahlung knüpfen, falls nämlich die Konjunktionsrichtung in den Leitstrahl zu Jupiter fällt oder in dessen über die Sonne hinaus geführte Verlängerung. Im ersten Falle sind ja die erregenden Durchgänge der beiden zwischen Jupiter und Sonne damit verknüpft, weshalb Zulenkung mit vorläufiger Hemmung eintreten muss. Bezüglich der näheren Auswirkung ist die Merkurstellung massgebend. Sobald auch er die gleiche Richtung einnimmt, also die drei innersten nahezu in Konjunktion stehen, muss die Hemmung überwiegen. Wenn jedoch nach einem halben Umlauf Merkur in Opposition zu Venus und Erde gerät, ist die *Auslösung* zum Meteoriteneinschlag in die Sonne gegeben, weshalb nun ein Fleckenmaximum auftaucht. Im zweiten Fall findet die Venus-Erdekonjunktion auf der zu Jupiter entgegengesetzten Seite statt, weshalb die *auslösenden* Oppositionen nahe sind und somit ein eventueller Merkurdurchgang zwischen Jupiter und Sonne ohne weiteres die Meteoriteneinstürze bewerkstelligen kann.

Diskussion 1926—Gleich zu Beginn des Jahres findet der letztangeführte Fall eine Anwendung. Die an sich hemmende Venus-Erdekonjunktion vom 7. Februar vollzieht sich in Verbindung mit der für Massenzustrahlung günstig wirkenden gemeinsamen Opposition zu Jupiter (25. und 31. Januar). Durch diese Stellung wird dem seitens des Merkurdurchganges (10. Februar) zwischen Jupiter und Sonne erregten Meteoritenstrom freie Bahn gelassen. In der Tat erblicken wir in der Nähe des Oppositionstermines der Erde vom 21. bis 25. Januar hohe Tageszahlen über 100. Man würde sie an und für sich *zwischen* den Oppositionsdaten von Erde und Venus in den letzten Monatstagen erwarten. Aber da macht sich bereits die Hemmung der Venus-Erdekonjunktion geltend, die eben auch die Einwirkung der Merkur-Jupiterkonjunktion noch einige Tage zurückhält, so dass die nächste hohe Zahlengruppe über 100 erst in der Nähe der auslösenden Merkuroppositionen zu Erde und Venus vom 13. bis 15. Februar zur Geltung gelangen kann. Da Jupiter seinen grossen Einfluss im Jahre 1926 seiner im Jahre 1927 erfolgenden Konjunktion zu Uranus verdankt, die vom vorhergehenden Stillstand (von Jupiter aus gerechnet), also seit 1925 bereits vorauswirkt, so ist auch auf die Konjunktionen und Oppositionen von Venus und Erde zu Uranus zu achten. Daher ist es nicht zu verwundern, wenn an den betreffenden Op-

positionsterminen (4. und 16. März) noch Nachzügler der hohen Fleckenwerte sich einstellen. Am ersten Termin wirkte auch die Auslösung vom Merkur-Perihel (9. März) mit, weshalb damals die hohen Zahlen länger währten.

Die zweite Gruppe der grossen Fleckenzahlen, getrennt durch das deutliche Minimum im April, ist durch die nacheinander auftretenden Durchgänge von Merkur, Venus, und Mars zwischen dem Hauptplaneten und der Sonne bedingt. Vorläufig kann nur der zuerst auftretende (jener vom Merkur am 11. Mai) eine Tageszahl über 100 (am 8.) wecken. Im übrigen hemmen die damit verknüpften Konjunktionen—die Merkur-Venuskonjunktion vom 21. April und die Venus-Marsbegegnung vom 18. Mai. Erst bei den nächsten *auslösenden* Faktoren (so weit sie Merkur und Venus betreffen), nämlich bei der Merkur-Venusopposition am 24. Juni, wozu die Venus-Uranuskonjunktion sich gesellt (sowie am 4. Juli die Erde-Venusquadratur), erscheinen wieder Werte über 100. Wieder durch eine deutliche Minimumrinne (ja sogar durch einen fleckenlosen Tag am 18. Juli) voneinander abgesondert, erhebt sich die dritte Einstrahlungsgruppe im August im gemeinsamen Durchgange von Merkur und Erde zwischen Jupiter und Sonne (10. und 15. August). Weil ihre Konjunktion vom 7. August hemmt, werden einerseits die schon bei der Annäherung an Jupiter gesammelten Massen bereits (terrestrisch besprochen) beim der unteren Merkur-Sonnenkonjunktion vorhergehenden Stillstand (23. Juli) zum Teil zur Sonne gelenkt, weshalb Ende Juli einige Werte über 100 erstehen, anderenteils können sie erst nach Beseitigung der Hemmung der Merkur-Venuskonjunktion zur Sonne gelangen. Als nächster Termin käme die Zeit nach dem darauffolgenden Stillstand (17. August) in Betracht. Gleichzeitig hemmt jedoch die Merkur-Marskonjunktion. Insbesondere macht sich bereits die starke Hemmung der Merkur-Venuskonjunktion vom 8. September geltend. Es bedarf daher einer stärkeren Auslösung die erst bei der Opposition des Merkur zur Erde am 19. September eintritt, wozu auch das Venus-Perihel am 15., dann die Erde-Uranuskonjunktion am 21. und die Venus-Jupiteropposition am 25. September mithelfen. Diesen vier vereinigten Auslösungsfaktoren gelingt es, in der zweiten Septemberhälfte 5 Tage mit Fleckenzahlen über 100 hervorzurufen. Immerhin ist die Hemmung der Merkur-Venuskonjunktion vom 8. September noch zu nahe. Erst nach Beseitigung derselben erfolgt die gänzliche Ueberstellung der Meteoritenmassen an die Sonne beim nächsten Auslösungsfaktor, nämlich bei der Venus-Uranusoppostion am 15. Oktober. Im November erscheint noch eine vierte Gruppe von Einstrahlungsursachen. Es durchzieht am 7. Merkur den Leitstrahl Sonne-Jupiter, wobei schon am 21. die Venus-Erdeopposition nachfolgt. Im ersten Augenblicke möchte man meinen, man hätte es mit einer ähnlich günstigen Situation zu tun wie im Februar, wo zum Merkurdurchgang gelegentlich der Venus-Erdekonjunktion deren gemeinsame Opposition zu Jupiter fördernd

Tabelle der Sonnenflecken-Relativzahlen für 1926 *mit Bemerkungen über Einstrahlungsursachen, Auslösungsfaktoren, und Hemmungsursachen*[1]

ag	Jan.	Feb.	März	Apr.	Mai	Juni	Juli	Aug.	Sep.	Okt.	Nov.	Dez.
1	93	40	50	35	62	62	104	76	*A*45	29	51	115
2	*A*71	42	68	30	53	73	76	62	21	23	65	85
3	58	*A*38	103	29	56	47	79	89	28	37	59	57
4	37	41	*A*103	29	68	*A*98	*A*64	101	21	34	*H*73	55
5	34	34	119	22	86	*A*80	43	82	39	37	58	89
6	56	29	97	23	53	83	46	79	42	53	44	68
7	50	*AH*35	100	30	74	95	35	*H*40	43	69	*E*27	70
8	76	44	103	27	102	86	34	50	*H*29	116	31	65
9	90	32	*A*82	50	92	92	24	67	28	70	35	38
10	92	*E*42	63	30	88	91	17	*E*62	35	85	50	69
11	84	99	47	34	*E*93	94	28	59	30	144	38	90
12	69	94	61	37	89	62	16	70	33	132	39	92
13	57	142	45	58	83	75	7	75	37	151	39	116
14	55	150	60	71	60	80	11	55	55	*A*133	*A*37	80
15	61	162	89	65	86	57	13	*E*47	*A*74	110	38	106
16	78	*A*142	*A*110	69	84	65	8	45	73	113	*H*39	96
17	94	127	79	69	65	50	0	*H*40	89	83	37	93
18	76	85	72	63	*H*71	55	0	40	112	60	26	94
19	95	*A*99	69	75	80	50	14	51	*A*111	55	20	86
20	82	67	46	58	63	52	22	53	106	31	53	75
21	*103*	59	38	*H*41	75	44	41	74	*A*105	50	*A*101	*A*87
22	95	41	11	35	67	*E*39	52	58	89	40	112	103
23	*102*	48	42	14	40	55	55	64	85	40	113	68
24	87	49	35	14	27	*A*58	99	78	68	37	101	106
25	*A*124	64	37	16	31	56	72	73	*A*70	62	106	95
26	71	56	45	18	22	90	125	62	70	93	110	91
27	78	53	47	15	23	92	114	55	101	85	*A*88	52
28	38	45	18	19	43	103	115	55	80	95	*A*89	82
29	51	....	30	41	*E*54	111	109	55	57	49	64	61
30	48	....	31	39	52	109	98	49	49	61	73	29
31	*A*21	....	*H*38	....	50	....	100	43	....	40	....	49
M	71.8	70.0	62.5	38.5	64.3	73.5	52.3	61.6	60.8	71.5	60.5	79.4

Bemerkungen—*E* = Einstrahlungsursachen: 10. Feb., *MkJ;* 11. Mai, *MkJ;* 29. Mai, *VkJ;* 22. Juni, *AkJ;* 10. Aug., *MkJ;* 15. Aug., *EkJ;* 7. Nov., *MkJ*.

A = Auslösungsfaktoren: 2. Jan., *EP;* 25. Jan., *EoJ;* 31. Jan., *VoJ;* 3. Feb., *VP;* 7 Feb., *VkE;* 16. Feb., *MoE;* 19. Feb., *MoV;* 4. März, *VoU;* 9. März, *MP;* 16. März, *EoU;* 4. Juni, *MoE;* 5. Juni, *MP;* 24. Juni, *MoV* und *VkU;* 4. Juli, *VqE;* 1. Sep., *MP;* 15. Sep., *VP;* 19. Sep., *MoE;* 21. Sep., *EkU;* 25. Sep., *VoJ;* 14. Okt., *VoU;* 14. Nov., *VoA;* 21. Nov., *VoE;* 27. Nov., *MoV;* 28. Nov., *MP;* 21. Dez., *MoA*.

H = Hemmungsursachen: 7. Feb., *VkE;* 31. März, *MkE;* 21. Apr., *MkV;* 18. Mai, *VkA;* 7. Aug., *MkE;* (17. Aug., *MkA*); 8. Sep., *MkV;* 4. Nov., *EkA;* 16. Nov., *MkE*.

[1]Abkürzungen: *A*, Mars; *E*, Erde; *J*, Jupiter; *L*, Mond; *M*, Merkur; *N*, Neptun; *P*, Perihel; *S*, Saturn; *U*, Uranus; *V*, Venus; *k*, Konjunktion; *q*, Quadratur; *o*, Opposition; *u*, untere Sonnenbegegnung.

hinzutrat. Aber es fehlen diesmal die Beziehungen zum grossen Planeten. Sie waren ja von Mitte August an schon vorausgenommen und hatten, wie eben dargelegt wurde, im Vormonate Oktober die Meteoritenzulenkung bereits geleistet. Somit ist diese Venus-Erdeopposition hauptsächlich nur als Auslösetermin zu beachten. Anfangs November trat eine Doppelhemmung auf wegen der Erde-Marskonjunktion am 4. und der Erde-Merkurkonjunktion am 16. Daher konnte von Seiten des Merkur erst bei seiner Opposition zu Venus am 27. im Verein mit seinem Perihel am 28. die Tätigkeitserregung auf der Sonne erfolgen. In der Tat stellten sich auch die hohen Tageszahlen zwischen den beiden Auslösungsterminen, nämlich zwischen 21. und 27. November ein. Der Dezember weist nur mittelstarke Zahlen auf. Er ist weder von einem bedeutsameren Hemmungs- noch Zulenkungsfaktor beeinflusst. Es ist nur mehr das Ausklingen der Tätigkeit zu beobachten. Ein einziger, untergeordneter positiver Umstand, die Merkur-Marsopposition vom 21. Dezember, welche wegen der vorausgegangenen Mars-Erdekonjunktion stärker als sonst zu bewerten ist, zeigt den Effekt in einem Einzelwert über 100 am 22.

Während man bei Darstellung der Maxima der Sonnentätigkeit immer neben den eigentlichen positiven Ursachen (den Einstrahlungserregungen) auch das Ausweichen vor den Hemmungen zu berücksichtigen hat, wirken die Hemmungsursachen am Termine selber. Die markanteste Hemmung erziehlt stets die Merkur-Venuskonjunktion. Die erste vom 21. April war überdies nahe verknüpft mit der Merkur-Erdebegegnung vom 31. März. Im ganzen April wirkte keine bemerkenswerte positive Ursache ein. Schon in der allgemeinen Regel kam zum Ausdruck, dass bei einer Venus-Erdekonjunktion abwechselnd Vermehrung und Verminderung der Fleckenzahlen aufscheint, so zwar, dass Vermehrung bei der gemeinsamen Merkuropposition and Verminderung bei den gemeinsamen Merkurkonjunktionen eintreten müsse. Diese beiden Konjunktionen, welche den ganzen April beherrschen, sind daher von bevorzugter Natur. In der Tat weist denn auch der April das deutlichste Monatsminimum auf. Die nächste derartige Merkur-Venuskonjunktion vom 8. September stand bereits länger von der am 7. August vorhergegangenen Merkur-Erdekonjunktion ab. Zudem trafen in der Zwischenzeit zwei positve Faktoren und zwar Einstrahlungsursachen, nämlich die Durchgänge von Merkur (10. August) und Venus (15. August) ein. Es konnte somit die Hemmung nicht mehr so hervortreten. Rechnen wir jedoch das Monatsmittel vom 15. August an, woselbst die letzte positive Ursache eintraf, bis zum 15. September, an dem der nächste positive Auslösungsfaktor im Venus-Perihel nachfolgte, so ergibt sich als Mittelwert 46′.0, also eine Grösse, die unter allen Monatsmitteln mit Ausnahme vom April liegt. Von der zweitstärksten Hemmungskonjunktion, nämlich Merkur-Erde, folgt noch eine am 16. November nach, die nahe mit der Erde-Marsbegegnung vom 4. November verknüpft ist. Infolgedessen hatte November

trotz der früher besprochenen hohen Zahlen im letzten Monatsdrittel nur den drittniedrigsten Mittelwert 55′.0 aufzuweisen. Der zweitniedrigste 48′ 3 erschien im Juli, in welchem sosusagen positive und negative Faktoren fehlten. Es war die frührere Einstrahlungsgruppe bereits ausgeklungen. Eine neue wurde erst Ende des Monates wieder eingeleitet. Mangels an erregenden Meteoriteneinstürzen musste daher die Sonne zur Ruhe kommen.

Die hier für 1926 gezeigte Darstellungsart der planetaren Fleckenbeeinflussung wurde an einem Dutzend Jahren in den Tagestabellen und an einem weiteren, aus verschiedenen Fleckenperioden ausgewählten in den Monatsmitteln erprobt und dürfte die richtige Deutung des Flecken-Phänomens anbahnen.

II. Bezüglich der planetaren Einflussnahme auf den Erdmagnetismus, der vielfach indirekt auf dem Umwege über die Sonne erfolgt, wurden im anfangs erwähnten Aufsatze folgende vier Hauptregeln aufgestellt:

(I.) Die erste Gruppe derselben betrifft eine von der Sonne aus gerechnete Konjunktion zweier der vier äussersten Planeten: Neptun, Uranus, Saturn, und Jupiter. (*a*) Wenn in der Nähe vom Konjunktionstermin (etwa in einem Abstand von höchstens einem Jahre) fast gleichzeitig Venus und Erde zwischen Sonne und den in Konjunktion stehenden Planeten hindurchgehen, dann wird ein starkes Monatsmaximum erreicht. (*b*) Wenn aber umgekehrt beim Durchzug der Venus zwischen Sonne und den beiden Planeten die Erde auf der anderen Seite gegenüber steht, dann erscheint ein tiefes Minimum im Monatsmittel. An sich schwächer, aber mitunter wegen genauer zeitlicher Koinzidenz gleich stark wie Venus wirkt Merkur.

Anmerkung zu (*a*)—In einem Maximalmonate treten nun nicht etwa konstant hohe Zahlen auf. Es sind vielmehr in dem zu beobachtenden Wellenspiele von periodischen Anschwellungen und Verminderungen *besonders hohe und lang gedehnte Wellenberge* zu sehen. Als Hauptregulator erscheint der Mond, ganz ähnlich wie Myrbach es angibt. Auch unabhängig von Venus kommen bei einer, von der Sonne aus gerechneten Konjunktion zweier der vier äussersten Planeten um die Zeit ihrer gemeinsamen Sonnenopposition durch eine Reihe von Monaten deutliche Wellenberge an den Tagen der gemeinsamen Mondkonjunktion. Wenn in einem Zeitabstande von einem oder höchstens zwei Monaten zur gemeinsamen Sonnenopposition noch eine solche von einem dritten der vier äussersten Planeten sich hinzugesellt, bzw. die untere Sonnenbegegnung von Venus oder Merkur, dann ziehen die Mondkonjunktionen zu den letztgenannten Planeten die Wellenberge von den Terminen der Doppelmondkonjunktionen ab. Wenn aber umgekehrt eine planetare Konstellation aufscheint, die niedrige erdmagnetische Zahlen zur Folge hat, wie, z.B., die Sonnenkonjunktionen eines äusseren Planeten, bzw. die *oberen* Sonnenbegegnungen von Venus oder Merkur, dann wirken diese Konjunktionen, falls ihre Termine nahe mit jenen der doppelten Mondkonjunktionen zusammentreffen, repulsiv verschiebend.

(II.) Die in der ersten Regel hervorgehobene, von der Sonne aus gerechnete Konjunktion zweier der vier äussersten Planeten wirkt nicht immer gleich stark. Es ist vielmehr auch die Konjunktionsrichtung massgebend. Sehr günstig ist die Antiapexrichtung, also etwa die heliozentrische Länge 90°, ungünstig die

Längenstellung bei 270°. Eine solche Stellung von Jupiter (oder auch Saturn) bei 270° kann veranlassen, dass für das ganze Jahr die erdmagnetischen Zahlen geschwächt werden.

(III.) So oft von der Sonne aus zwei der vier äusseren Planeten in Opposition treten und nahezu gleichzeitig Venus und Erde auf (von der Sonne aus) entgegengesetzter Seite diese Oppostionslinie durchqueren, herrscht nicht nur rege Sonnentätigkeit vor, es zeigen sich auch grössere erdmagnetische Schwankungen. Für die Erde tritt die Hauptwirkung dann ein, wenn nahe der Sonnenoppsition des einen Planeten die Konjunktion der Venus zum anderen erfolgt. Es bilden sich kräftige Wellenscheitel für die Zeitpunkte der Mondkonjunktionen zu dem von der Sonne aus in Opposition tretenden Planeten aus.

(IV.) Wenn in einem Jahre keine der vorhin genannten Regeln zur Anwendung kommen kann, dann bewirkt die Jupiter-Sonnenopposition in Verknüpfung mit der unteren Venus-Sonnenbegegnung sicher das Maximum der Monatsmittel. Umgekehrt erziehlt ein Monat, in welchem die obere Sonnenkonjunktion der Venus sich mit jener von Jupiter oder auch Saturn vereinigt, die Periode der kleinsten Zahlen. Schwächer als Venus, aber in gleichem Sinne wirkt Merkur.

Diese Regeln wurden damals an Jahrestabellen 1925 und 1921 erläutert und finden im Diagramm für 1926 neuerliche Bestätigung. In der Schwankungskurve sind die hervorragendsten Maxima, welche die früheren Tabellen in Fettdruck anzeigten, durch die Nummern 1 bis 16 abgezählt und die tiefsten Minima, welche die Tabelle in Fraktur brachte, durch lateinische Bushstaben *a* bis *n* hervorgehoben. Für 1926 kommt vor allem die III. Regel in Betracht wegen der Opposition des Jupiters zu Neptun. Im Diagramm befinden sich unterhalb der Sschwankungskurve einige nach oben gerichtete Pfeile, welche die positiven Ursachen andeuten sollen, von denen nach obigen Regeln die Sonnenoppositionen der äusseren und die unteren Sonnenbegegnungen der inneren Planeten die wichtigsten sind. In der zweiten, auf das zweite Halbjahr Bezug nehmenden Zeile findet sich für den Beginn vom August zunächst eine untere Sonnenbegegnung vom Merkur vor (*Mu*), welche von dem vorhergehenden Stillstand an stärkere Störungen hervorzurufen pflegt, wie sie auch diesmal im Scheitel 11 deutlich ersichtlich sind. Dann erscheint die Jupiter-Sonnenopposition, abermals begleitet von einer Kurvenspitze, die aber noch gerade kein vollwertiges Maximum darstellt, worauf die an sich hemmende Neptun-Sonnenkonjunktion eintritt, die aber wegen der Gegenstellung zu Jupiter auch positiven Einfluss nimmt, woran der Pfeil mit der Bemerkung III erinnern soll. Nach dieser III. Regel tritt die Hauptwirkung ein, wenn nahe der Sonnenkonjunktion des einen Planeten die Venuskonjunktion zum anderen erfolgt, wobei kräftige Wellenscheitel bei den Mondbegegnungen zum opponierenden Planeten entstehen. Diese Venus-Neptunkonjunktion ist nun im Diagramm durch einen längeren

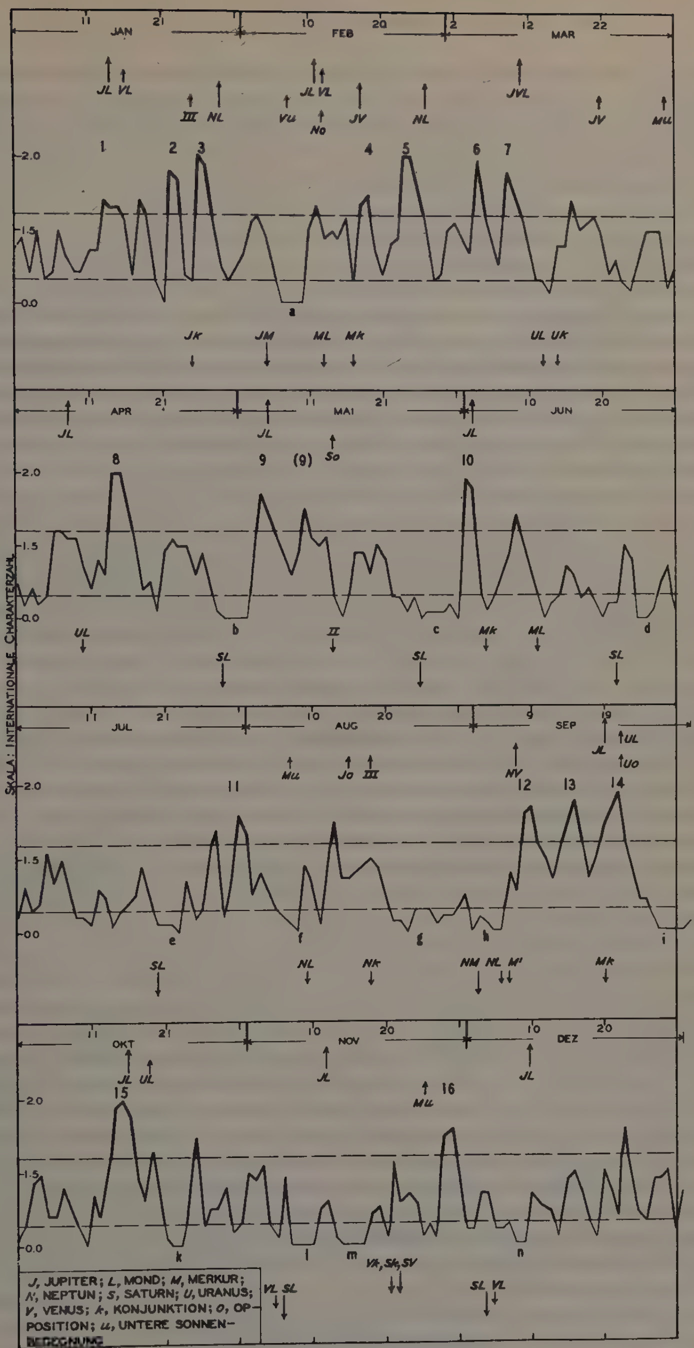

Diagramm für 1926

Pfeil angemerkt. In der Tat erscheinen dabei drei maximale Scheitel 12, 13, 14, und zwar der letzte zur Zeit der geneinsamen Mondbegegnungen zu Jupiter und Uranus (Vgl. I. Regel). Dadurch ist eine Welle erregt, die auch bei der nächsten gemeinsamen Mondbegegnung das Maximum 15 hervorruft, bei der zweitnächsten das stärkste Minimum (*l* und *m*) durch einen Zacken unterbricht und bei der drittfolgenden das Wellental *n* rasch beendet. Ende November weckt eine untere Merkur-Sonnenbegenung noch den letzten Scheitel 16.

Bezüglich des eben erwähnten deutlichsten Minimums im November trifft die IV. Regel zu, da die obere Venus-Sonnenbegegnung unmittelbar mit der Saturn-Sonnenkonjunktion zusammentraf. In der Tat wies der November das niedrigste Monatsmittel der Schwankungszahlen auf, insbesondere zeigte sich in der Nähe der betreffenden Konstellation das bedeutsamste Minimum *m*, ferner erstanden bei den flankierenden Mondbegegnungen zu Venus und Saturn die Minima *l* und *n*. Alle diese negativ wirkenden Phänomene sind im Diagramm durch nach abwärts gerichtete Pfeile erkenntlich gemacht. Wie oben bereits erwähnt, knüpfen sich die gewöhnlichen schwächeren Minima der erdmagnetischen Schwankungen an vereinzelte Sonnenkonjunktionen der äusseren und die oberen der inneren Planeten. Im Diagramm findet sich eine ähnliche Häufung von Wellentälern wie im November nur noch im August vor bezüglich der Minima *g* und *h*. In der Tat kommen da zwei Hemmungsursachen zusammen: die Neptun-Sonnenkonjunktion und die obere Merkur-Sonnenbegegnung. Ihr Einfluss konzentriert sich bei der von der Erde aus gerechneten Konjunktion der beiden (*NM*), wobei das Minimum *h* auftritt, während die Neptunkonjunktion von *g* und die Sonnenbegegnung von Merkur von *i* begleitet ist. Auch bei der vorhergehenden Neptun-Mondkonjunktion erscheint bereits das Minimum *f*. Das Minimum *k* wäre einem Mars-Einfluss zuzuschreiben, der aber wegen der sekundären Bedeutung dieses Planeten in die obigen Regeln nicht einbezogen wurde.

Im ersten Halbjahr fallen die Konstellationen nicht so günstig ein, dass man ohne weiteres die obigen Regeln anwenden könnte. Die ersten Scheitelwerte 1 bis 5 sind aus einer Interferenz von IV und III entstanden. Die IV. Regel besagt nämlich, dass die Jupiter-Sonnenopposition in Verknüpfung mit der unteren Venus-Sonnenbegegnung sicher das Maximum der Monatsmittel bewirkt. Nun war die untere Venuskonjunktion im Februar zwar nicht mit der Sonnenopposition des Jupiters, sondern nur mit jener vom Neptun verbunden. Ganz der Regel entsprechend, erscheinen demnach auch an den beiden Terminen der Mondbegegnungen zu Neptun, welche dessen Sonnenopposition umschlossen, die Scheitel 3 und 5. Es wirkte diese Neptunopposition deutlicher also sonst ein, weil eben die Gegenstellung zu Jupiter nach III kräftigend hinzukam. In Folge dessen zeigte sich bei der vorhergehenden Mondkonjunktion zu Jupiter und Venus der Scheitel 1; bei der nächstfolgenden derartigen Mondbegegnung wurde das Minimum *a* rasch beendigt,

wobei es wegen der Interferenz mit dem Wellental nur zu einer mittleren Erhebung kam. Insbesondere musste es nach den Regeln I und III zu einer starken Wellenerregung kommen bei der Venuskonjunktion zu Jupiter, die erstmals im Februar und dann, da Venus inzwischen rechtläufig geworden war, nochmals im März eintrat. In der Tat setzte am erstgenannten Termin der Scheitel 4 ein, worauf an den Zeitpunkten der folgenden Mond-Jupiterkonjunktionen die Scheitel 7, 8, 9, 10 sich anreihten. Die Verspätung des Maximums 8 ist durch die gleichzeitig auftretende Hemmung der Mondbegegnung zu Uranus, dessen Sonnenkonjunktion eben vorhergegangen war, begründet. Der negative Einfluss dieser Konjunktion des Uranus zur Sonne interferierte mit dem positiven seitens der unteren Merkur-Sonnenbegenung, weshalb in den späteren zwei Monatsdritteln vom März weder ein ausgesprochenes Maximum noch Minimum sich entfalten konnte. Von den beiden oberen Merkur-Sonnenkonjunktionen im ersten Halbjahr fiel die erste mit einer Fülle von positiven Ursachen zusammen. Freilich wäre die kurz vorhergegangene Jupiter-Sonnenkonjunktion an sich sehr stark hemmend, aber sie wandelte sich wegen der Gegenstellung zu Neptun (III) in einen Förderungsfaktor um. Zwar zeigt sich in der Schwankungskurve nahe dem Termine der Jupiter-Sonnenkonjunktion Ende Januar ein tiefer Einschnitt nach abwärts, es rang sich jedoch die Hemmung erst bei der Konzentration der beiden Phänomene (Jupiter-Sonnenbegegnung und obere Merkur-Sonnenkonjunktion) durch, nämlich bei der von der Erde aus erfolgten Konjunktion von Jupiter und Merkur (*JM*). Daselbst tauchte die Ruhepause *a* auf. Dass auch im Juni bei der zweiten dieser oberen Merkur-Sonnenbegegnungen und der damit verbundenen Merkur-Mondkonjunktion nur *Einbuchtungen* nach abwärts ohne ausgesprochenes Minimum auftraten, ist freilich eine kleine Schwäche dieses Deutungsversuches, dürfte aber den Grund in der umkehrenden Wirkung der Saturnopposition nach II suchen lassen. Bezüglich der planetaren Hemmungsursachen kommt nämlich für 1926 auch die II. Regel in Betracht. Saturn stand bereits nahe genug der Hemmungsstelle 270°, weshalb die sonst verstärkende Saturn-Sonnenopposition in die gegenteilige, hemmende Wirkung umschlug. Diese Hemmung kam schon bei der vorhergehenden, dann bei der nachfolgenden Saturn-Mondkonjunktion in den Minimis *b* und *c* zum Ausdruck; auch die darauf folgenden Saturn-Mondbegegnungen ergaben noch die Ruhestellen *d* und *e*. Man kann die sichere Erwartung hegen, dass man noch genauer in die Komplikation der einzelnen Wellen eindringen wird und dann nicht bloss—wie in dieser Skizze—die bedeutsamsten Spitzen nach oben und unten, sondern den gesamten wechselnden Verlauf der Schwankungskurve zu erfassen vermag. Freilich wird man dabei nebst diesen Konjunktionen und Oppositionen zur Sonne auch die relative Stellung der Planeten zur Erde, ihre Breitenbewegung, dann die Nachwirkung einer Erregung auf der Erde selber in Erwägung ziehen müssen.

Parsch-Salzburg, Oesterreich.

NOTES

(See also page 262)

30. *Zürich Sunspot-Data*—In accordance with a resolution passed at the meeting of the International Astronomical Union at Leiden, Holland, in July 1928, the Eidgenössische Sternwarte at Zürich will publish, under the auspices of the Union, beginning with the current year, a quarterly bulletin giving the character-numbers for all solar phenomena for the central sector of the Sun. These data are intended primarily to assist investigators engaged in the study of the relationships of terrestrial phenomena which appear to depend upon corpuscular emissions from the Sun.

31. *Magnetic Survey, Western Hawaiian Islands*—The Steamer *Discoverer*, Lieutenant *T. H. Maher*, Commanding, of the United States Coast and Geodetic Survey, has recently been engaged in a survey of the islands and reefs of surrounding waters lying to the westward of the main group of the Hawaiian Islands. Observations were made by compass-declinometer at Nihoa Island (23°*N*, 162°*W*) and Necker Island (23.5°*N*, 165°*W*). As these are volcanic rocks with practically no covering, it is not surprising to find that the values are highly disturbed with a range of 34° in the Nihoa Island and 30° on Necker Island. However, magnetometer-observations were made on French Frigate Shoals (24° *N*, 166° *W*) which is flat and has a deep covering of sand, and the values appeared normal. Accordingly, this should make a useful repeat-station at some future date if it can be recovered.

32. *San Juan Magnetic Observatory*—The San Juan magnetic observatory was severely damage by the hurricane of September 13, 1928. The office building and garage were blown away and the seismograph building was damaged. The instrument was damaged beyond repair. The roofs were partly taken off the variation and absolute buildings but the magnetic instruments escaped damage. The relief of *Wallace M. Hill* by Lieutenant *E. R. Hand* was in progress and both were at the observatory while the hurricane was going on, but they left for San Juan, several miles away, in time to take refuge in a substantial building and escaped injury. Plans are being worked out for the re-erection of the necessary buildings.

33. *Atmospheric Potential-Gradient Records at Manila*—Rev. *C. E. Deppermann*, S.J., of the Weather-Bureau staff at Manila writes that beginning in October 1927, he has had a potential-gradient photographic recorder in operation. He first adopted a Wulf bifilar electrometer and subsequently replaced it by a Mascart electrometer for which, because he had no amber, sulphur insulation was used. The results have been satisfactory and Father *Deppermann* expects upon the completion of a year's records to prepare an article on the results, preliminary considerations of which indicate interesting correlations with thunderstorms and wind-directions.

34. *Commission for Terrestrial Magnetism of the Aeroarctic*—In connection with the general meeting of the *Aeroarctic* in Leningrad last June, deliberations were held on June 19 and 21, 1928, by its Commission for Terrestrial Magnetism in which *Rose* and *Haussmann* of the Commission, and *Weinberg*, *Grotewahl*, and *Stenz*, took part. The other two members of the Commission, *L. A. Bauer* and *D. la Cour*, were unable to be present.

RELATIVE SUNSPOT-NUMBERS FOR THE CENTRAL ZONE OF THE SUN'S DISC FOR THE 11-YEAR PERIOD 1917 TO 1927

By W. Brunner

For the purpose of studying the relationship between terrestrial and solar phenomena particularly with regard to terrestrial phenomena which appear to depend upon corpuscular emissions projected from the Sun in limited streams, it may be interesting to have the daily relative sunspot-numbers not only for the whole disc but also for a certain central sector nearer the line joining the center of the Sun and the Earth.

The following tables give the relative sunspot-numbers for a central zone equal to a circular surface of the semi-diameter of the Sun's disc. A spot passing near the center of the disc takes from the east to the west end of the central zone a little more than four days. The numbers given are dependent alone on observations at Zürich Observatory made during 1917 to 1926 by A. Wolfer and during 1926 to 1927 by W. Brunner.

Relative sunspot-numbers for the central zone of the Sun

Day	Year 1917											
	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1	..	11	..	..	58	77	50	43	24	22	0	38
2	26	..	14	7	50	44	23	28	9	44	20	..
3	..	7	7	..	60	..	33	23	15	18	17	78
4	37	21	17	0	50	10	56	14	30	0	27	53
5	34	..	..	7	37	14	..	7	58	9	39	28
6	12	7	45	..	..	26	71	43	81	21	44	0
7	32	..	37	10	37	44	70	61	49	34	76	0
8	..	77	..	7	12	17	..	113	25	26	53	0
9	16	95	44	0	22	20	..	122	26	..	13	21
10	..	100	43	0	29	27	..	179	26	..	8	..
11	..	70	64	0	46	25	64	166	31	..	13	..
12	43	12	..	0	69	21	157	117	..	11	..	59
13	45	34	..	..	55	90	88	68	35	8	..	74
14	28	..	0	73	54	89	80	89	43	..	..	69
15	17	42	..	..	42	76	72	56	43	..	53	64
16	..	46	0	..	37	74	36	41	9	9	65	..
17	..	59	31	..	50	29	31	55	19	..	43	48
18	..	..	46	55	70	66	24	79	55	39	..	..
19	..	..	39	28	109	65	31	63	42	..	13	..
20	..	38	49	28	105	42	43	22	83	..	..	..
21	..	..	43	34	57	55	34	11	128	..	..	..
22	..	..	..	12	44	19	..	23	167	34	66	..
23	..	0	..	39	29	20	16	16	169	45	77	..
24	..	14	..	25	11	39	26	13	118	38	74	..
25	..	7	..	..	13	70	32	20	90	31	..	..
26	..	8	57	41	10	43	49	34	44	22	..	..
27	28	0	25	36	49	68	89	43	26	38	44	53
28	..	0	..	19	88	77	92	51	8	..	..	65
29	16	..	26	35	118	31	101	32	7	44	..	53
30	..	..	50	58	77	62	82	28	10	..	..	40
31	29	..	31	..	..	..	36	40	..	0	..	..

Relative sunspot-numbers for the central zone of the Sun (Circular surface of a semi-diameter of the Sun's disc)

Day	1918 Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
1	28	..	..	..	..	40	71	103	23	61	25	17
2	..	..	..	26	55	64	75	..	33	10	22	10
3	..	..	16	13	34	113	59	26	17	16	21	..
4	28	23	17	49	11	132	..	8	17	21	14	35
5	40	..	16	58	16	91	94	..	0	31	26	19
6	9	17	16	44	20	91	64	33	0	41	7	..
7	..	10	..	32	28	53	76	47	8	23	8	8
8	..	10	0	..	42	14	83	44	..	..	13	0
9	31	0	8	22	65	16	51	26	23	40	..	..
10	..	7	23	35	68	..	..	10	26	..	13	9
11	46	35	52	26	41	12	41	8	27	..	0	13
12	46	34	49	35	51	..	22	29	..	33	..	29
13	..	43	87	39	38	0	17	36	48	..	0	..
14	25	..	96	47	19	0	23	48	62	..	16	23
15	..	37	..	..	28	0	49	55	56	..	32	..
16	..	53	29	..	31	..	15	86	23	28	34	0
17	16	68	38	16	18	..	0	110	0	..	..	13
18	..	82	32	7	22	7	0	101	0	..	..	13
19	70	48	16	..	21	16	20	37	0	..	..	..
20	67	16	31	..	17	28	17	34	..	26	76	..
21	94	..	8	..	16	22	62	11	43	47	110	53
22	92	8	0	27	13	24	100	19	96	65	76	..
23	..	..	18	..	0	20	68	32	..	86	..	..
24	67	..	33	8	16	20	91	34	..	..	22	..
25	35	..	34	8	22	10	51	60	74	..	45	63
26	22	26	56	21	38	14	37	54	35	..	36	21
27	..	25	60	48	52	0	25	55	21	22	..	35
28	49	11	49	..	47	0	..	61	61	20	..	10
29	52	..	41	42	19	14	47	14	62	19	..	..
30	..	..	35	23	19	30	67	7	..	..	26	25
31	..	..	16	..	20	..	61	14	..	..	..	..

Day	1919 Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
1	32	0	53	..	39	51	22	8	27	..	..	26
2	8	..	..	8	46	54	..	7	19	..	..	7
3	0	17	46	0	49	26	25	14	43	..	..	14
4	0	73	18	51	..	36	17	22	16	7	33	44
5	..	88	..	51	20	..	20	16	22	0	..	28
6	0	..	0	56	24	90	22	0	0	0	23	..
7	7	..	0	52	55	44	39	22	7	0	8	..
8	..	61	30	..	69	23	23	42	7	..	..	14
9	63	40	48	45	80	0	..	49	0	..	30	..
10	..	8	63	..	63	23	33	53	0	20	..	0
11	75	9	65	10	59	8	8	62	12	64	17	8
12	43	52	34	8	29	0	43	46	46	83	..	..
13	..	62	..	0	22	32	..	16	53	..	0	..
14	11	43	..	7	16	67	71	14	31	..	..	33
15	14	43	..	14	0	61	88	0	33	10	0	..
16	..	..	..	13	0	88	29	7	26	7	..	..
17	..	0	43	..	40	82	16	..	0	8	10	..
18	21	..	26	18	84	79	9	73	0	14	..	..
19	..	15	14	0	125	104	8	86	0	11	..	7
20	19	26	8	0	130	82	23	90	0	10	..	7
21	8	25	7	0	58	53	26	72	12	8	11	..
22	0	14	..	25	61	65	..	20	20	..	..	9
23	..	..	0	22	47	62	24	10	29	..	..	..
24	..	0	0	..	29	41	..	0	57	..	0	..
25	..	9	9	37	15	..	44	25	41	..	7	17
26	..	0	16	25	20	..	32	37	18	..	..	16
27	..	8	34	9	10	..	28	30	25	16	31	..
28	20	20	42	..	16	43	10	21	24	..	49	..
29	0	..	42	23	24	32	7	7	..	8	43	..
30	..	..	..	22	25	21	0	0	..	38	23	..
31	..	..	43	..	44	..	0	10	..	83	..	18

Relative sunspot-numbers for the central zone of the Sun (Circular surface of a semi-diameter of the Sun's disc)

Day	Year 1920											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
1	43	0	18	0	16	9	7	15	36	24	7	..
2	..	0	8	0	14	13	27	0	..	7	..	..
3	..	0	0	0	13	30	33	0	..	..	19	10
4	..	0	0	0	..	27	30	7	..	10	53	7
5	..	20	0	13	7	31	20	0	..	..	50	..
6	0	15	12	7	7	12	0	0	0	16	31	..
7	..	30	27	0	23	0	0	0	0	16	..	..
8	0	21	..	9	41	0	10	0	7	..	..	..
9	0	22	68	0	28	0	10	0	0	15	..	..
10	..	8	70	0	31	..	11	0	0	..	0	..
11	..	..	39	0	18	35	13	0	14	..	..	..
12	..	8	31	7	7	29	8	0	30	48	..	..
13	19	38	14	..	13	..	7	0	24	44	0	..
14	22	53	8	0	..	10	10	..	11	43	0	..
15	40	47	0	18	23	0	0	..	0	22	0	..
16	36	20	..	16	17	0	0	14	0	17	0	..
17	16	37	0	20	0	..	0	31	0	17	..	..
18	14	41	..	17	0	0	0	23	0	..	0	..
19	11	47	85	..	0	7	7	14	..	..	8	24
20	0	25	125	0	0	20	7	7	..	..	9	..
21	..	67	163	0	0	25	14	8	0	0	7	..
22	23	32	142	0	..	15	9	0	0	..	..	16
23	42	..	120	..	7	20	23	0	7	..	0	..
24	47	26	31	0	0	22	..	..	0	..	0	..
25	49	26	0	0	0	38	..	0	17	61	0	27
26	73	27	0	..	32	11	..	9	29	..	10	16
27	82	31	0	0	34	24	..	8	53	31	..	11
28	97	29	14	10	33	25	7	8	66	20	15	..
29	..	19	17	..	23	17	13	7	42	7	..	21
30	25	..	8	13	10	10	16	0	40	0	..	20
31	..	..	7	..	21	..	8	0	..	0	..	30

Day	Year 1921											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
1	19	..	0	11	0	7	72	22	0	0	0	0
2	0	0	7	0	0	17	45	0	0	0	..	..
3	..	..	10	14	0	24	32	0	0	0	..	..
4	37	22	7	10	0	13	13	0	0	0	..	..
5	13	20	0	8	0	11	43	0	0	0	0	..
6	..	11	..	0	0	11	80	0	0	..	0	..
7	17	..	..	0	0	0	65	0	0	0	0	0
8	7	..	0	0	..	34	36	0	0	7	0	0
9	0	..	0	9	..	..	29	0	0	0	..	..
10	9	..	0	18	0	42	21	0	11	0	0	0
11	19	..	19	20	0	45	11	10	13	0	..	..
12	22	17	29	39	24	28	10	..	0	13	0	10
13	30	15	20	7	65	8	11	14	0	11	0	..
14	47	0	34	9	56	7	7	8	0	17	0	26
15	..	8	28	..	49	7	9	0	7	8	..	..
16	..	..	17	..	37	0	17	0	0	..	..	36
17	38	18	15	16	11	0	14	0	13	0	..	..
18	16	28	..	0	0	0	13	8	33	7	..	..
19	20	37	..	..	0	..	7	0	33	10	..	..
20	8	48	7	13	0	0	10	..	..	10	..	17
21	..	0	0	20	8	..	0	11	26	..	7	20
22	0	11	0	28	7	..	0	23	0	11	16	24
23	..	17	0	37	11	13	0	29	0	..	..	13
24	..	7	0	17	8	10	7	7	8	26	..	0
25	8	0	9	..	7	0	0	..	13	15	..	0
26	13	0	25	11	7	0	0	40	..	28	..	0
27	7	0	28	8	0	7	9	55	0	23	..	..
28	16	0	40	8	..	36	10	41	0	..	..	8
29	0	..	21	0	0	67	35	22	0	21	..	8
30	0	..	9	0	0	68	39	8	0	8	..	0
31	0	..	9	..	0	..	33	0	..	0	..	..

Relative sunspot-numbers for the central zone of the Sun (Circular surface of a semi-diameter of the Sun's disc)

Day	Year 1922												Year 1923											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
1	..	0	77	..	28	0	0	0	7	10	0	..	14	..	0	12	0	8	0	0	0	8	..	..
2	0	11	89	7	31	0	0	0	..	..	..	13	7	0	0	10	0	0	0	0	0	0	0	0
3	0	..	71	..	27	0	0	0	0	0	..	19	0	0	0	0	0	10	0	0	0	0	0	..
4	7	0	26	16	..	0	0	0	0	0	0	16	..	..	0	0	0	..	0	0	0	0	..	0
5	..	..	42	10	10	0	8	0	0	0	0	16	..	0	0	0	0	0	0	0	0	..	0	..
6	..	16	56	12	0	0	17	15	0	0	0	22	0	..	0	0	0	0	0	0	0	0	..	..
7	8	32	61	8	0	0	12	8	7	..	0	..	0	0	..	0	0	0	0	0	0	0	..	0
8	..	21	..	0	0	7	13	0	..	..	0	8	..	0	0	..	0	0	0	0	7	..	..	0
9	..	18	..	..	0	0	..	0	..	..	..	11	0	0	0	0	0	0	0	0	0	..	10	0
10	13	13	..	0	0	0	8	0	..	0	12	10	0	0	0	0	..	0	0	0	0	0	7	8
11	8	22	76	0	0	..	7	0	0	..	11	..	0	..	..	0	0	0	0	0	10	0	..	..
12	16	42	69	0	0	7	7	0	..	0	..	0	0	..	..	0	8	0	0	0	10	0	..	..
13	..	35	59	0	..	0	0	0	0	8	..	..	0	9	0	8	9	0	0	0	8	..	0	..
14	0	27	23	0	0	0	0	0	0	7	..	0	0	8	..	..	0	0	0	0	10	7	0	..
15	..	22	0	0	0	0	..	0	..	..	0	..	0	..	..	0	0	0	0	0	..	11	0	..
16	11	..	0	..	0	0	0	0	0	..	0	0	..	7	0	0	0	0	0	0	0	8	..	0
17	..	0	0	..	0	0	0	0	7	10	0	0	..	..	0	..	0	0	0	0	8	0	0	0
18	7	0	0	..	0	..	0	0	7	..	..	..	0	0	0	0	0	0	..	0	..	0	0	0
19	..	0	0	0	0	0	..	0	8	..	0	0	0	0	0	0	0	13	0	0	7	0	..	..
20	..	0	0	0	0	0	0	0	7	..	..	0	..	0	7	0	0	8	0	7	..	..	0	..
21	..	0	..	..	0	9	22	0	0	0	8	..	0	0	0	0	0	9	0	0	0	0	0	..
22	..	..	..	0	0	7	28	0	0	..	..	..	0	0	12	14	7	8	8	..	0	..	0	..
23	..	8	..	0	0	0	14	..	0	..	0	..	0	0	0	13	0	7	7	0	0	20	0	..
24	0	7	0	7	0	0	19	20	0	..	..	..	0	0	0	10	0	0	7	0	0	..	..	..
25	..	7	0	17	0	0	15	0	0	..	0	..	..	..	0	7	11	0	7	0	0	19	..	0
26	..	8	10	..	0	..	0	0	0	..	0	10	..	0	0	0	..	..	0	0	0	22	..	..
27	..	..	24	..	0	0	0	8	7	..	0	23	..	0	0	..	0	17	0	0	7	7	..	..
28	..	55	28	14	7	0	0	10	7	..	..	24	0	0	0	..	..	20	0	0	0	0	..	0
29	0	..	26	7	8	0	0	0	..	..	..	..	..	..	0	0	0	31	0	0	10	0	7	..
30	0	..	19	7	13	0	0	0	8	0	0	..	..	..	8	0	0	29	0	0	8	0	0	..
31	..	..	7	..	16	..	0	7	..	0	..	25	..	..	16	..	0	..	0	..	..	0	..	..

Relative sunspot-numbers for the central zone of the Sun (Circular surface of a semi-diameter of the Sun's disc)

Day	Year 1924 Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
1	..	0	0	..	0	0	0	8	42	11	..	0
2	..	0	0	..	0	7	0	0	..	..	0	..
3	0	..	0	..	0	0	..	0	11	8	0	..
4	0	..	0	0	0	0	31	0	..	8	..	..
5	0	0	..	0	0	0	..	7	7	15	..	..
6	0	..	..	..	0	0	14	7	0	7	..	0
7	..	..	0	0	0	0	8	8	0	7	..	..
8	0	0	0	0	..	0	8	13	0	8	0	0
9	0	..	0	0	0	0	9	7	0	0	..	..
10	0	0	0	0	0	0	22	0	..	0	0	..
11	..	0	0	0	0	7	40	0	..	0	..	..
12	0	0	0	0	0	8	55	0	26	0	..	..
13	..	..	0	0	13	14	40	0	29	0	..	19
14	0	..	0	0	22	..	29	..	23	0	..	8
15	..	..	0	0	29	9	0	0	14	..	13	..
16	0	..	0	0	34	0	0	0	7	0	..	..
17	0	..	0	0	15	0	0	0	0	0	14	19
18	0	..	0	0	7	0	0	0	0	22	..	..
19	0	0	0	20	0	0	0	14	0	15	9	..
20	0	..	0	43	0	0	0	14	9	11	..	..
21	..	0	0	26	0	..	0	17	8	16	38	..
22	0	0	0	35	7	..	15	11	7	0	..	..
23	..	0	8	0	..	..	15	9	7	..	..	..
24	..	0	8	0	7	0	12	0	..	..	..	0
25	0	0	0	0	..	0	7	0	0	9	18	0
26	0	7	..	0	..	0	0	..	0	..	0	0
27	0	0	0	0	..	0	0	0	0	14	0	0
28	..	0	0	0	10	0	0	7	25	16	0	..
29	0	0	..	..	7	0	0	..	26	..	..	0
30	0	..	..	0	0	0	..	51	20	7	..	0
31	0	..	..	..	0	..	..	33	..	..	..	..

Day	Year 1925 Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
1	0	8	..	0	0	11	0	0	24	..	..	..
2	0	0	0	0	0	22	9	0	10	38	..	26
3	0	0	0	0	0	40	9	16	22	40	..	..
4	0	0	..	0	17	35	8	0	38	22	18	28
5	0	0	0	..	23	0	8	8	28	..	..	26
6	0	0	..	..	36	8	28	16	35	21	..	..
7	0	..	..	..	28	16	34	8	24	10	..	..
8	0	17	0	7	18	39	45	14	14	12	10	34
9	0	17	0	7	7	46	..	26	39	..	..	35
10	0	10	0	7	7	28	7	17	11	..	7	..
11	0	9	0	..	..	28	0	11	8	..	..	36
12	8	30	0	36	..	35	8	23	7	22	..	18
13	..	46	0	9	17	34	8	18	0	8	..	..
14	0	..	..	7	17	..	18	7	0	..	..	..
15	..	36	..	16	17	8	26	0	21	0	..	..
16	..	0	20	7	8	0	29	0	28	..	..	95
17	..	0	21	13	26	0	21	0	..	..	..	68
18	..	0	19	0	25	0	11	0	9	59	..	35
19	..	17	0	0	24	7	20	8	0	38	..	28
20	..	8	7	..	25	0	29	7	9	..	..	28
21	0	0	0	22	29	..	22	7	25	76	..	37
22	..	..	..	27	38	0	0	0	44	46	..	26
23	0	7	..	8	38	0	0	0	65	40	50	32
24	0	0	..	..	0	0	0	0	..	..	..	..
25	..	0	..	..	7	0	11	..	21	31	58	..
26	..	0	13	..	0	0	15	23	20	17	..	..
27	..	0	25	..	14	0	15	50	38	23	23	..
28	0	7	0	0	13	0	17	57	..	0	13	45
29	0	..	0	0	..	0	25	50	15	0	..	..
30	..	..	0	0	7	8	7	..	..	0	7	16
31	0	..	0	..	0	..	..	28	..	..	..	0

Relative sunspot-numbers for the central zone of the Sun (Circular surface of a semi-diameter of the Sun's disc)

Day	Year 1926 Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
1	0	..	..	0	0	45	51	26	9	15	..	..
2	..	34	49	0	20	55	38	26	0	8	..	..
3	..	32	74	15	40	..	8	30	7	..	..	..
4	28	18	52	7	32	..	41	29	11	18	..	..
5	..	0	77	8	48	19	35	18	16	7	..	..
6	35	0	..	8	28	..	38	15	21	0	..	..
7	..	0	29	7	35	19	..	16	13	14	17	..
8	0	0	..	0	17	57	..	37	13	35	22	..
9	0	..	22	7	14	79	0	39	0	46	26	25
10	7	..	20	14	50	52	0	9	0	59	22	72
11	26	7	16	23	37	42	8	..	0	73	23	..
12	39	..	..	8	58	9	7	11	13	61	19	..
13	35	89	21	25	..	7	8	7	14	53	16	..
14	17	88	..	29	26	0	7	0	41	45	16	40
15	..	91	32	12	22	23	14	18	28	51	22	..
16	..	..	16	13	24	25	9	22	16	31	26	61
17	34	28	23	34	23	37	7	12	40	41	33	..
18	..	26	28	28	28	31	0	11	85	28	20	..
19	..	..	29	28	31	19	8	12	81	8	7	8
20	..	26	29	0	35	28	14	10	85	7	19	8
21	53	24	7	0	52	32	14	17	49	..	..	0
22	..	7	0	0	57	30	18	7	28	..	..	40
23	68	7	..	0	16	27	30	18	22	..	42	..
24	..	0	0	0	0	0	48	24	29	0	53	..
25	52	0	7	0	0	..	52	42	40	25	..	..
26	..	..	15	..	0	16	34	37	..	32	37	..
27	0	0	0	0	0	30	..	28	10	27	45	0
28	..	..	..	0	10	48	58	18	9	..	66	0
29	..	..	0	0	0	55	..	8	13	20	32	..
30	10	..	0	7	0	53	59	10	16	38	34	..
31	21	..	..	..	19	..	77	18	..	29	..	19

Day	Year 1927 Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
1	..	63	16	8	37	10	37	15	16	7	7	..
2	..	61	10	20	37	12	49	7	19	0	0	..
3	32	79	24	31	40	0	40	0	32	8	16	..
4	..	58	31	32	8	..	34	14	13	17	26	..
5	28	47	0	..	11	7	48	10	17	17	..	..
6	31	..	0	50	73	45	41	19	14	21	17	..
7	..	72	37	31	77	49	34	8	0	53	..	..
8	35	74	..	..	52	74	15	0	13	47	11	20
9	..	77	42	27	34	68	19	0	20	50	25	..
10	..	65	23	..	29	30	..	0	31	..	39	..
11	58	41	36	47	38	16	8	0	32	..	40	..
12	..	20	29	77	73	9	7	10	31	37	50	20
13	14	9	..	76	61	17	0	36	52	..	26	..
14	0	22	16	86	23	15	0	42	72	23	50	..
15	0	19	..	74	8	18	8	61	73	..	56	11
16	..	35	23	49	17	16	13	8	28	..	..	..
17	14	..	31	77	17	31	24	10	28	8	59	0
18	28	..	61	65	23	..	26	28	..	8	35	0
19	..	24	49	41	29	8	14	32	39	0	16	0
20	..	32	40	C	52	10	19	19	36	9	..	..
21	..	15	52	7	46	10	11	21	29	33	27	13
22	22	21	52	18	46	12	17	45	10	..	..	..
23	25	33	23	28	36	30	19	..	37	10	44	23
24	..	17	8	23	25	29	24	..	..	31	..	27
25	0	28	17	7	28	26	8	11	..	31	52	32
26	15	34	17	33	34	31	28	7	0	12	40	..
27	8	31	..	..	50	40	41	37	17	7	19	32
28	25	12	0	22	22	21	22	44	22	0	..	..
29	21	..	14	47	29	56	..	30	23	20	..	..
30	29	..	9	44	22	43	0	9	..	16	..	..
31	59	..	14	..	21	..	17	0	..	37	..	..

NOTE ON THE ULTRAVIOLET LIGHT OF THE SUN AS THE ORIGIN OF AURORÆ AND MAGNETIC STORMS

By H. B. Maris and E. O. Hulburt

A theoretical investigation has been made of the outlying regions of the atmosphere of the Earth and of the effect of sunlight on these regions; certain of the conclusions are given in this preliminary note. By the usual methods the temperatures and the pressures of the atmosphere to great heights were calculated for a quiet Sun, that is for the Sun in its normal state, with no terrestrial auroræ or magnetic storms. Because of the unequal balance at cold temperatures between the solar energy absorbed in the ultraviolet by the atmospheric gases and the energy re-emitted in the infra-red by the gases, the daytime temperatures above 100 kilometers were found to increase with the height above the surface of the Earth until at 300 or 400 kilometers temperatures of 1000° Kelvin seem reasonable. (There is of course nothing novel in this, although we have been interested in working the matter out more exactly perhaps than has been done heretofore.)

At heights above 400 kilometers the atmosphere becomes very rare and the free-paths of the particles very long, practically infinite in fact, were it not for the actions of gravity and of sunlight. A portion of the atoms (or molecules) of these remote regions dance up and down, receiving upward thrusts from thermal impacts below and falling back under gravity, and may be expected to reach heights up to 1000 kilometers, but hardly above this. During the daytime a number of the outlying atoms are excited by the short-wave ultraviolet light of the Sun to which they are exposed. A normal atom upon collision with the excited atoms may receive a high velocity (collision of the second kind), a velocity sufficient perhaps to send it beyond the gravitational attraction of the Earth. A normal atom may also attain a high velocity by absorbing the energy of recombination of a positive ion and an electron. Therefore there are a number of high flying atoms in the outer reaches of the atmosphere and these give rise to interesting effects. Many of them might leave the Earth never to return were it not for the sunlight. They do hasten out towards interplanetary space but under the photoelectric influence of the solar ultraviolet radiations they soon become ionized. Once ionized they are caught by the magnetic field of the Earth and as ion-pairs are constrained to spiral around the line of magnetic force eventually being brought back to the Earth. If the line ends in sunlit latitudes the ion may start off on another wild heavenward chase, or it may wander down to more prosaic lower levels. If the magnetic line ends in night latitudes, as in the polar regions after sun-down, the ion-

pairs upon plunging to the lower levels hand over their energy of recombination to the atmosphere of those regions. This energy may go into heat or it may, if conditions are suitable, reappear as light, such as the auroral display. (In passing we may note that a complete theory of the rate of escape of planetary atmospheres should contemplate the ideas of the foregoing paragraphs.)

Quantitative estimates indicate that an appreciable fraction of the solar ultraviolet energy is carried to a zone 20° to 30° from the magnetic poles by high flying ion-pairs ejected to heights of 20,000 to 40,000 kilometers above the Earth. The estimates have depended upon a knowledge of such quantities as the intensity of sunlight in the extreme ultraviolet, the number of excited atoms, absorption-coefficients (Einstein's B), etc. These quantities are imperfectly known, but as far as can be seen reasonable values have been used. For the case of a quiet Sun the amount of energy transferred to the auroral zones appears about sufficient to supply the energy of a mild auroral display. This is in keeping with the fact that the aurora occurs on a rough average two or three times a week throughout the year with no very marked seasonal variations. From the velocities of ejection of the high flying atoms and the time which elapses before they become ionized it comes out that a majority of the ion-pairs plunge to the Earth in a zone roughly 20° to 30°, or 1400 to 2000 miles, from the magnetic poles, and that relatively few get down to regions within 1000 miles of the magnetic poles. This is in accord with the observed 23-degree zone of maximum auroral frequency. Since the auroral energy at a given magnetic meridian is regarded as being brought in from the sunlit latitudes on roughly the same meridian one would expect (as is observed) the aurora to be brighter (or to occur more often) in the early hours of the night than in the later hours. In brief, the main characteristics of the aurora receive logical explanation on the present theory.

When the Sun becomes active the magnetic effects of the high flying ions, perhaps inappreciable during intervals of solar quiescence, become pronounced and result in the magnetic storms. We assume that the Sun when active sends out a sudden blast of ultraviolet light. For example, if 1/10,000 part of the solar surface which normally is at a temperature of 6000°, were removed and there were exposed the black-body radiations from regions at a temperature of 30,000°, the total ultraviolet energy in the wave-lengths 500 to 1000 angstroms would be increased by 10^5 whereas the solar-constant would be increased by only one per cent.

Actually in times of solar activity variations of three or more per cent in the solar-constant are observed and the increase at wave-length 3500 angstroms is such as to suggest even higher temperatures than 30,000°. The number of the high flying ions is then increased by, say, a factor of 10^5 over the number formed during undisturbed solar periods. The ions, no matter what their velocities are, under the combined action of gravity and the Earth's magnetic field move at right-angles to these two vectors with a velocity ap-

proximately mg/He, the positive and negative ions moving in opposite directions. Thus there is an electric current around the Earth, the lines of current flow being roughly circles in planes perpendicular to the magnetic axis of the Earth with centers on the axis. (Each cubic centimeter of the high atmosphere of course remains electrically neutral at all times in spite of the current flowing through it.) Calculation of the energies and processes involved indicated that the blast of solar ultraviolet light produces enough high flying ion-pairs to give rise to a current of 10^5 amperes for an hour or so. This causes a magnetic field of the order of 10^{-3} gauss simultaneously over the whole Earth, which is the order of magnitude observed in the first phase of the world-wide magnetic storms. It has long been realized that an equatorial current would account for the world-wide magnetic storms and several hypotheses have been suggested as to the cause of the current; the hypotheses have, however, contained a number of difficulties which are absent from the present theory. (It is possible, of course, that this theory may turn out to contain difficulties of its own which are not seen at the present time.)

The high flying ions descend in large numbers to the zones about 25° from the magnetic poles and form there diamagnetic concentrations of considerable intensity. On the assumption that the blast of ultraviolet light does not die away abruptly but continues with lessening intensity for a day or so, the diamagnetic polar atmospheric concentrations wax with the day and wane with the night. Upon working out the changes in the Earth's magnetic field caused by this diamagnetism agreement is found in practically every detail with the observed complicated diurnal storm-variations in the three magnetic field-components at all latitudes.

On the present views we may regard the Earth as a photoelectric cell which responds to the ultraviolet radiations of the Sun, and the magnetic observatories as galvanometers in the electrical circuit of the terrestrial photoelectric cell.

Naval Research Laboratory,
Washington, D. C.
October 11, 1928

NOTE ON THE RADIAL MAGNETIC GRADIENT OF THE SUN

By Ross Gunn

Dr. Hale and his collaborators at Mt. Wilson Observatory have studied the general magnetic field of the Sun by spectroscopic measurements of the Zeeman-effect. These researches established the fact that at any given level the distribution of the magnetic field was very similar to the terrestrial distribution. A study of the radial distribution showed that the field decreased radially several thousand times as fast as would be expected if the Sun were uniformly magnetized. This rapid radial variation has

made it very difficult to obtain a consistent view of the general magnetic fields of the Sun and Earth.

In a recent paper[1] the writer pointed out that under certain conditions of ionization, temperature, pressure, and magnetic field, a true diamagnetic effect exists which is due to the motion of ions or electrons spiralling about an impressed magnetic field. On the Earth the conditions in the Kennelly-Heaviside layer satisfy the requirements and it was shown that the diamagnetic effect of this layer would account for the solar component of the diurnal variation of terrestrial magnetism.

Such data as are now available from spectroscopic studies indicate that the ion-pressures in the regions of large radial magnetic gradient are sufficiently low to satisfy the conditions for a large diamagnetic effect. Further calculations show that the intensity of magnetization of the diamagnetic regions is sufficiently large to account for the observed gradients. A tentative extrapolation of the effect of the regions where diamagnetism of the layer ceases to play an important part indicates that the polar magnetic field-strength of the Sun is of the order of 1000 gauss.

The study of diamagnetism in the atmosphere of the Sun in regions of large radial magnetic gradient has led to a method of estimating the ion-pressures from observed magnetic data. Calculations show that the pressure is a logarithmic function of the altitude above the photosphere.

If we assume that the gas is in purely gravitational equilibrium the pressures may be represented approximately by

$$N = N_0 e^{-Zm_H gh/RT}$$

where N_0 is roughly 2×10^{16} ions per cc and $Z = 3.3$; m = mass of H_2 atom $= 1.66 \times 10^{-24}$ grams; g = acceleration due to gravity $= 2.7 \times 10^4$ cm per sec^2; h = altitude above photosphere in cm; R = gas-constant $= 1.37 \times 10^{-16}$ erg per deg; T = absolute temperature $=$ 6000°.

Pressures determined on the basis of the theory agree with estimates of pressures from unrelated sources. The low value obtained for the mean atomic weight of the particles making up the Sun's atmosphere, namely, 3.3, is taken to mean that either a radial electric field exists on the Sun or that the atmosphere is not even approximately in gravitational equilibrium.

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[1] Phys. Rev., v. 32, July 1928 (133-141).

THE UPPER ATMOSPHERE

By H. B. Maris

Abstract

Wind Currents and Diffusion—The components of a uniformly mixed atmosphere kept free from winds would separate by diffusion, heavier molecules moving down and light molecules moving up. The flow of separation would be uniform at all heights; for example, in the air 1.07×10^8 molecules of helium would be expected to move up past any horizontal square centimeter per second. This upward flow of the helium would establish gravity equilibrium for helium gas above 140 km in one day, above 120 km in five days and above 106 km in fifty days. Wind-currents, it is estimated, would cause a movement of the air above 100 km to lower altitudes once in five to twenty-five days.

Temperature of the Upper Atmosphere—Radiation and absorption coefficients lead us to expect a temperature change of approximately 140° C between day and night during the summer and 30° C during the winter, at a height of 80 km. Carbon dioxide is found to be more important than water-vapor in determining the radiant energy which escapes from the Earth's outer atmosphere, and the conclusions are reached that the ice-ages can be explained by slight changes in the carbon-dioxide content of the air.

Density of the Upper Atmosphere—New tables of density are compiled which show helium-content and hydrogen-content roughly 1/100,000 of those previously calculated for heights greater than 130 km. The conclusion is reached that above 300 km the atmosphere can not be assumed to be in a state of equilibrium, but that the percentage of very high-energy molecules would be far higher than would be given by a Maxwellian curve for thermal equilibrium.

Introduction

It has been clearly recognized that winds are an important factor in determining the composition and condition of the atmosphere at different heights, but an exact mathematical expression for this complex factor is entirely beyond our present knowledge. Perhaps this explains why wind-action has been neglected in calculations of the composition of the atmosphere, although it has been recognized that the temperatures of the lower atmosphere (below 12 km) are dependent on the stirring action of wind, and exact calculations were made showing each gas in gravity-equilibrium with its own partial pressure at all heights. The general problem of an absorbing atmosphere, and the problem of a grey sphere warmed by sunlight and cooled by radiation have been carefully studied, exact calculations of radiation-equilibrium have been made, but they were based on the assumption of an atmosphere absorbing and radiating as a uniform grey body and no account was taken of diurnal or seasonal changes. As a consequence of these studies the assumption that diffusion of the air is complete, and that the temperature of the atmosphere is independent of day-and-night or seasonal changes has been generally accepted.

Diffusion in a uniformly mixed atmosphere kept entirely free from winds would be far from complete at the end of a thousand years, and it is obvious that the temperature of an atmosphere

which absorbs more than ten per cent of the sunlight must vary with variation in the intensity of the sunlight passing through it. In this paper the time-rate of diffusion is calculated, and mixing action of winds is estimated; calculations are made for temperatures of radiation-equilibrium for winter and summer, day and night using known absorption-coefficients; and from these calculations new density-tables for the gases of the atmosphere are computed.

Wind Currents and Diffusion

Writers, who have discussed the change in composition of the atmosphere with altitude, have recognized that the stirring of winds would keep the air of uniform mixture at all altitudes if gravity and diffusion did not always separate the gases to a certain extent by causing a downward flow of the heavier and an upward flow of the lighter molecules. Most writers have assumed the diffusion separation to be practically complete [1, 2] and have constructed tables showing each gas in gravity-equilibrium with its own partial pressure at all altitudes. Chapman and Milne[3] have questioned this neglect of the wind as a mixing agent and have constructed density-tables based on the assumption of uniform mixture in the atmosphere from sea-level to different arbitrarily chosen elevations with gravity-equilibrium for each gas above the given elevation. No attempt has been made at a solution of the problem of the relation between separation by diffusion and wind mixing.

One obvious method of attacking the problem is to assume an atmosphere uniformly mixed at all altitudes and then kept entirely free from winds while diffusion and gravity work to restore equilibrium. For such a case, the rate of diffusion is easily calculated by equation (830), taken from Jeans (*l. c.*), corrected by Jeans' equation (839).

$$N_1 = \left(\frac{1.34}{3}\right)\left(\frac{n_1\lambda_2C_2+n_2\lambda_1C_1}{n_1+n_2}\right)\frac{\partial n_d}{\partial Z} \qquad (1)$$

Where N_1 is the excess of a given type, for illustration let us say helium, crossing unit area of the Z-plane in unit time, n_1 is the number of helium molecules per cc, n_2 is the total number of other molecules per cc, $\frac{\partial n_d}{\partial z}$ is the diffusion gradient or departure from equilibrium-condition in number of helium-molecules per cm in the direction of Z, λ is the mean free-path and C average velocity of the respective molecules.

If we assume uniform mixture of all gases and $\frac{\partial n_Z}{\partial Z}$ is the rate of decrease of air-molecules per centimeter with height, then the decrease of molecules of helium is expressed in the equation

[1] Jeans, Dynamical theory of gases, 1925, p. 341.

[2] Humphreys, Physics of the air, 1920, p. 169.

[3] *Q. J. R. Met. Soc.*, v. 46, 1920, p. 357.

$$\frac{\partial n_1}{\partial Z} = K_1 \frac{\partial n_Z}{\partial Z} = K_1 n_Z \frac{(1-10^{-\alpha_2 \Delta Z})}{\Delta Z} \tag{2}$$

where $n_1 = K_1 n$, ΔZ is a small increment of Z and α_2 is the logarithmic factor for expressing the density of air in a gravitational field according to the equation

$$d_Z = d_0 10^{-\alpha_2 Z}$$

If we assume equilibrium for helium-gas, the rate of decrease in molecules with height is given by the equation

$$\frac{\partial n_1}{\partial Z} = K_1 n_Z \frac{(1-10^{-\alpha_1 \Delta Z})}{\Delta Z} \tag{3}$$

where α_1 is from the equation

$$d_Z = d_0\, 10^{-\alpha_1 Z}$$

for expressing the density of helium at any height Z. In an atmosphere of uniform mixture the difference between equations (2) and (3) will then give the gradient of molecules which supports diffusion and we then have

$$\frac{\partial n_d}{\partial Z} = K_1 n_Z \frac{(10^{-\alpha_2 \Delta Z} - 10^{-\alpha_1 \Delta Z})}{\Delta Z} \tag{4}$$

Substituting this value in equation (1) and assuming $\Delta Z = 1$ centimeter we have

$$N_1 = 0.45\ K_1 n_Z (K_1 \lambda_2 C_2 + K_2 \lambda_1 C_1)\ (10^{-\alpha_2} - 10^{-\alpha_1}) \tag{5}$$

Since $10^{-\alpha_2} = (P_Z - \omega_{Z_2})/P_Z$

where ω_{Z_2} is the weight of one cubic centimeter of air at pressure P_Z and

$$10^{-\alpha_1} = (P_Z - \omega_{Z_1})/P_Z$$

where ω_{Z_1} is the weight of one cubic centimeter of helium at Z then

$$10^{-\alpha_2} - 10^{-\alpha_1} = (\omega_1 - \omega_2)/P$$

Since K_1 is small and $K_2 = 1$, approximately, we get for equation (5) the expression

$$N_1 = 0.45\ K_1 n_2 \lambda_1 C_1\ (\omega_1 - \omega_2)/P \tag{6}$$

Equation (6) shows at once that N_1 is independent of the pressure since $n_2\lambda_1$, C_1, and $(\omega_1 - \omega_2)/P$ are constants. Therefore, if we assume a uniform mixture of air-gases at all heights and no convection, the excess number of molecules crossing a horizontal unit-area plane is a constant for all elevations.

Table 1 gives the constants needed to solve (6) for standard conditions of temperature and pressure. Column 1 gives the molecular weight, M, of each gas; column 2 gives the value of K or

ratio of the number of molecules per cc of the given gas to the total number of molecules present; column 3 gives the average velocity, C; column 4 gives the mean free-path λ; column 5 gives the product λC; column 6 gives the difference $(\omega_1-\omega_2)$; and column 7 gives the calculated value of N. For N greater than 0 molecules move downward and for N less than 0 molecules move upward. In these calculations, $0.45\ n_0/P_0$ is taken as 1.165×10^{16} and $\omega=M\ 4.46\times10^{-5}$.

TABLE 1—*Diffusion of atmospheric gases*

Gas	(1) M	(2) K	(3) $C\times10^{-4}$	(4) $\lambda\times10^{+6}$	(5) $C\lambda$	(6) $(\omega^1-\omega^2)10^{+4}$	(7) N
O_2	32	.21	4.25	6.4	.27	1.36	9.00×10^{10}
A	39.9	.0095	3.80	6.3	.24	4.87	1.28×10^{10}
CO_2	44	.0003	3.62	3.9	.14	6.67	3.26×10^{8}
K	82.9	.0001	2.63	4.9	.13	24.07	3.64×10^{8}
He_2	4.0	.000004	12.07	17.2	2.01	−11.45	-1.07×10^{8}
H_2	2.02	.0001	16.94	11.3	1.91	−12.03	-2.68×10^{9}

Equation (6) is of course independent of the pressure, but at the outer limits of the atmosphere an altitude must be reached where N decreases. It is necessary to examine the different terms of equation (5) to draw conclusions concerning the way in which they change when N decreases. Equation (5) can be rewritten

$$N_1=0.45\ K_1 n_Z\ (K_1\lambda_2C_2+K_2\lambda_1C_1)\ (10^{-a_x}-10^{-a_1})$$

In this equation 10^{-a_2}, the logarithmic term for change in density of air, the assumed initial condition for helium for the first expression, is replaced by the term 10^{-a_x}, the logarithmic term which expresses the actual change in density of helium at a given time and altitude. As we approach the upper limit of diffusion N_1, K_1, K_2, and 10^{-a_x} change with time for any given altitude but n_Z, λ_1, λ_2, C_1, C_2, and 10^{-a_1} remain constant. N must remain constant or decrease. Suppose that during the time t_0 to t_1 in the case of helium the value of K_1 has changed from 0.000004 to 0.0004. The term $K_1\lambda_2C_2$ is negligible as compared with the term $K_2\lambda_1C_1$ and the two expressions for N may be written

$$N_{t_0}=1.80\times10^{-6}n_Z\ (10^{-a_2}-10^{-a_1})$$

and $N_{t_0}=1.80\times10^{-4}n_Z\ (10^{-a_x}-10^{-a_1})$

but $N_{t_0}>N_{t_1}$

then $1.80\times10^{-6}\ (10^{-a_2}-10^{-a_1})>1.80\times10^{-4}\ (10^{-a_x}-10^{-a_1})$

finally $10^{-a_2}-10^{-a_1}>(10^{-a_x}-10^{-a_1})\ 100$ (7)

Expressed in words inequality (7) says that at an altitude, such that helium is four parts in ten thousand of the total atmosphere,

the departure of the actual density-curve for helium from the equilibrium-curve is less than one hundreth of the departure of the atmospheric density-curve from the helium-equilibrium density-curve, that is at this altitude the actual density-curve for the helium is practically identical with the helium density-curve of gravity-equilibrium. From inequality (7) the conclusion is drawn that for helium the error made in assuming an abrupt change from the density-gradient of uniform mixture to the gradient of gravity-equilibrium is very slight. In the following discussion and calculations the assumption is made that all gases are in uniform mixture below a certain region called the diffusion-level, above this region they are assumed to be in gravity-equilibrium with their own partial pressure.

Table 1, column 7, shows that hydrogen and helium molecules are moving up past any fixed plane in the lower atmosphere at the uniform rates of 2.68×10^9 and 1.07×10^8 molecules per second. Fig. 1 has been prepared to illustrate the downward motion of the diffusion-level of these gases with time. The curves show that after the first few hours a large change of time results in only a slight shift in the diffusion-layer and it is probable that the height of the layer will always be between 100 and 140 km during the night. We would expect it to be low near the poles and during the winter, and high near the equator and during the summer.

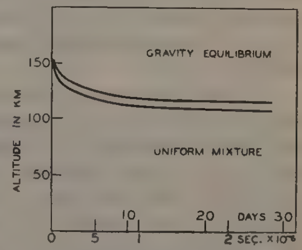

FIG. 1—Diffusion-level plotted against time for hydrogen (upper curve) and helium gases

It is interesting to note that the total mass of any gas in the Earth's atmosphere is given quite accurately by the equation

$$M_1 = M_0 K_1 \, m_1/m_0 \qquad (8)$$

where M_0 is the total mass of the dry air, K_1 is taken from column 3, Table 1, while m_1 and m_0 are the molecular weights of the given gas and air.

The calculations for the construction of Fig. 1 are subject to numerous errors. The temperature is assumed to be $0°C$ at all altitudes, local wind-disturbances are neglected, and the mean free-path λ is assumed to be the same for all gases. Currents resulting from the motion of the Earth and changes in thermal eqilibrium plus the effect of constantly changing conditions in the lower atmosphere will introduce a mixing of the upper atmosphere which will greatly retard the separation due to diffusion. Table 3 shows that during the summer the air above 100-km level during the night will move up 30 km at least before reaching thermal equilibrium during the day. This upward motion will, due to the Earth's rotation, result in a wind-velocity of 4 km per hour. This prediction has been verified by observations of meteor-trails. Of

nine daylight persistent meteor-trails reported by Trowbridge[4], seven drifted to the west, indicating a predominant drift of air-currents to the west during daytime at elevations of 50 to 150 km. Persistent meteor-trains observed at night likewise show a uniformity of motion of air-currents. Of 32 trails observed in the United States, 21 drifted north-northeast or east, while in England of 21 observed, 15 drifted east-southeast or south. All trains were immediately distorted by differences in the velocity of wind at different levels, and one observation by Denning showed a wind-velocity of 200 km per hour at 87 km elevation. These facts have led to the assumption that 5×10^5 seconds is a reasonable time to assume for the average time through which diffussion has progressed at 50° latitude. Of the sources of errors in diffusion-calculations listed above the probable error in selecting the time through which diffusion has progressed is by far the most important; however, an error of 100 per cent in estimating the time will introduce an error of only 10 to 15 km, in the calculated height of the diffusion-level.

Table 2 gives the calculations for the pressure at the diffusion-level for the different gases after 5×10^5 seconds. Column 1 gives n the total number of molecules above each horizontal square centimeter per dyne partial pressure, column 2 gives the number of molecules which pass a horizontal square centimeter in 5×10^5 seconds, and column 3 gives the resultant atmospheric pressure (P_g) at the base of the gravity-equilibrium and top of the uniform-mixture regions which is calculated as follows.

Let X be the pressure in dynes of the helium at the base of the gravity-equilibrium regions after diffusion has progressed 5×10^5 seconds. When diffusion started the number of helium-molecules above this level was, according to column 1, $2.13\times10^{19}X$; after diffusion the number of helium-molecules above had increased to $15.4\times10^{19}X$, the pressure is then given by $5.35\times10^{13}=15.4\times10^{19}X-2.13\times10^{19}X=13.87\times10^{19}X$, whence
$X=3.85\times10^{-7}$, or air-pressure $P_g=X/K=(3.85\times10^{-7})/(4\times10^{-6})$ $=9.63\times10^{-2}$.

Table 2—*Pressure at the base of the gravity-equilibrium region for the different gases of the air in dynes per square centimeter*

Gas	(1) $n{:}10^{-19}$	(2) $N{:}5\times10^5$	(3) P_g dynes
Air	2.13	....	....
O_2	1.93	4.50×10^{16}	1.07×10^{-1}
A	1.55	6.42×10^{15}	1.16×10^{-1}
CO_2	1.39	1.63×10^{14}	7.35×10^{-2}
K	0.75	1.32×10^{14}	1.32×10^{-1}
He_2	15.40	5.35×10^{13}	9.63×10^{-2}
H_2	30.85	1.34×10^{15}	4.67×10^{-2}

[4] *Astroph. J.*, v. 26, 1907, p. 95.

Table 3 gives the heights in kilometers at which the pressures of column 3, Table 2, are found under the temperature-conditions of winter and summer, day and night.

TABLE 3—*Height of diffusion-level in kilometers*

Gas	Winter night	Winter day	Summer night	Summer day
O_2	106	116	111	149
A	105	116	110	148
CO_2	108	119	113	153
K	104	115	109	146
He_2	107	117	112	150
H_2	111	122	117	158

We would expect the actual heights of the diffusion-layers to vary by about 10 km above and below those of Table 3.

Temperature of the Earth's Atmosphere

The temperature of the atmosphere decreases about 6° per km, with increasing altitude until a height of 10 to 15 km is reached with temperatures of 200° to 230° absolute. Above this height the gradient is small and is generally reversed. Hereafter these two regions will be spoken of as the lower and upper atmosphere respectively. The assumption is often made that the temperature of the upper atmosphere is that of equilibrium with radiation from the Earth. The radiation-equilibrium temperature for the Earth is approximately 259°K and an absorbing body like the air warmed by radiation at 259° from one side and cooled by radiation in both directions would reach equilibrium at approximately 219°. This supports the idea of radiation-equilibrium for the outer atmosphere, but if the atmosphere at 11 km were in equilibrium with black-body radiation from below during the night, it could not be in equilibrium during the day when more than 10 per cent of the Sun's radiation is absorbed in transit. Moreover the temperature at the base of the upper atmosphere is approximately 205° over the equator and 230° at 60° latitude[5]. It hardly seems possible that this change can be explained by a theory of radiation-equilibrium. The natural conclusion is then that we must turn to the condition of the lower atmosphere for an explanation of these temperatures.

A non-radiating gas in a gravitational field warmed only by absorption at the lower surface would be in equilibrium with an adiabatic expansion temperature[6] from its base to the outer limit. That is any volume of the gas taken from one altitude and moved to any other altitude would at all times be at the same temperature

[5] HUMPHREYS, Physics of the air, p. 58.

[6] JEANS, Dynamical theory of gases, p. 335.

as the surrounding gas and would neither gain nor lose heat through conduction. If this gas were, like our atmosphere, at the same time loosing energy by radiation through the outer surface, the lower denser and hence warmer strata would be cooled, but the outer colder regions would be warmed by radiation. The temperature at any point would be the resultant of two operations, the cooling due to adiabatic expansion, and loss or gain of heat by radiation-absorption and emission. The temperature of radiation-equilibrium for such a gas must always decrease with increasing altitude since the total radiant energy through unit volume must decrease with altitude by an amount equal to the decrease in radiation received from the gas above. If the atmosphere at 11 km were in radiation-equilibrium it would be warmer than the outer atmosphere at say 50 km because of absorption and re-radiation by the intervening layer. Different layers of air about the Earth must act very much like different blankets surrounding a warm body. If the blankets are in thermal equilibrium the temperature of each succeeding blanket must be lower than any of the blankets below it. If absorption-coefficients of the air are assumed to be uniform, a temperature of 219° at 11 km would be in equilibrium with a temperature of about 190° at 50 km (see Figs. 2 and 3); but the temperature increases from 11 km up as is shown by Humphreys[7] and Dines[8], therefore the air at the base of the upper atmosphere can not be in radiation-equilibrium.

The temperature of the lower atmosphere is approximately that of adiabatic equilibrium at the equator, but at higher latitudes the gradient is less, consequently the temperature of the base of the upper atmosphere is greater than it could be under adiabatic equilibrium. These conditions can be explained by the assumption of upward currents of warm moist air at the equator, a drift of cold air away from the equator at altitudes greater than 10 km, and a gradual increase in temperature resulting from absorption of radiation from the Sun and from the lower atmosphere. If the outward radiation of the lower air were that of black-body radiation at a temperature of 270°K and the temperature above 11km were 219°K, the temperature of the outer air would be increased 0.3° per day by radiation from below.

Discussions of radiation-equilibrium for the atmosphere are generally based on the three assumptions: Black-body radiation outward from below; uniform grey-body absorption and re-radiation by the air; and uniform optical properties of the air independent of altitude. The following discussion of these assumptions is given to illustrate the general nature of the radiation-problem and to show that we must not lose sight of the fact than no one of these three assumptions is even approximately correct. Above 11 km the radiation from below will be deficient in those wave-lengths which are strongly absorbed by water-vapor and carbon

[7]Physics of the air, pp. 52 and 53.

[8]*Mem. R. Met. Soc.*, v. 2, 1928, p. 18.

dioxide so that these gases at higher altitudes will absorb approximately as though they were in black-body radiation equivalent to a temperature of 219°K from below. On the other hand the ozone-bands are weakly absorbed in the lower atmosphere and would be expected to reach the outer atmosphere at approximately the original intensity radiated from the Earth, and would be absorbed in a region where water-vapor and carbon dioxide have become insignificant as either absorbers or radiators, so that for this region the effective temperature of the radiation would be approximately that of the Earth, independent of the intervening absorption of other bands by the water-vapor and carbon dioxide. A glance at Table 8 or Fig. 2 will show at once that absorption at one temperature

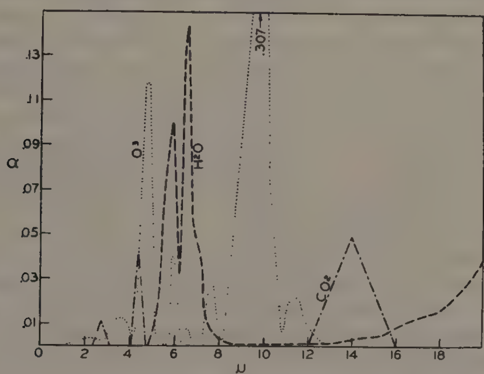

FIG. 2—Absorption-coefficients (α) plotted against wave-length (λ) for carbon dioxide, water-vapor, and ozone

and radiation at another can not as a rule be considered as simple grey-body absorption and radiation. Thus we find that all of our assumptions are invalid, but nevertheless they serve to illustrate the nature of the radiation-equilibrium problem.

The following temperature-calculations for the lower atmosphere were made for summer and winter conditions at 50° north latitude. The equation for adiabatic expansion of a gas as given by Jeans[9] is

$$TV^{(2/3)/(1+\beta)} = C = T_0 V_0^{(2/3)/(1+\beta)} \qquad (9)$$

where for air $\beta = 0.663$ and $PV^x = C = P_0 V_0^x$, $x = 1.401$. If we assume unit volume of air $PV^{1.401} = P_0$, then $V = (P_0/P)^{P_1V/1.401}$. At 11-km elevation, the volumes resulting are for winter 2.914, for summer 2.855; substituting in equation (9) we have for winter $T = 179°$ and for summer $T = 189°$. The above temperatures would be for the expansion of dry air, but of course the air is not dry at sea-level and as the air moves from sea-level to an altitude of 11 km,

[9]Dynamical theory of gases, p. 184.

moisture condenses releasing sufficient heat to raise the temperature roughly 20° in summer and 10° in winter. We then have for the temperatures of adiabatic expansion: Winter, 189°; summer, 209°. Comparing these values with those given by Humphreys[10], we have $(216° - 189°) = 27°$ difference for winter, and $(223° - 209°) = 14°$ difference for summer.

The question at once presents itself—can their difference be accounted for by the absorption of radiation? If we assume a solar-constant[11] of 1.35×10^6 ergs per second the radiation received at 50° latitude is $1.35 \times 10^6 \times \cos 50° = 8.7 \times 10^5$ ergs per second at noon or $8.7 \times 10^5 \times 2/\pi = 5.52 \times 10^5$ ergs per second average or 2.39×10^{10} total for 12 hours of daylight. The heat-capacity in ergs per degree C of the air above any pressure is roughly 10,000 times the pressure in dynes and at 11 km the heat-capacity is then 2.329×10^9 ergs per degree. If we assume that 10 per cent of the sunlight is absorbed to increase the temperature of the air above 11 km the increase would be 1° per day. The temperature at the base of the upper atmosphere can then be accounted for by adiabatic expansion plus direct heating for 4 to 10 days, and by the higher temperature and greater moisture-content of the air at the sea-level near the equator plus a movement of air-currents away from the equator at altitudes greater than 10 km.

The conclusion seems unavoidable that the base of the upper atmosphere is not in radiation-equilibrium, but is receiving energy from the Sun, from upper atmosphere, from the Earth, and from the lower atmosphere. From this conclusion we proceed to a detailed study of the absorption and emission of radiant energy by the upper atmosphere. This question has been discussed quite fully by E. Gold[12] and the absorption-coefficients of Tables 4 and 5 are calculated from data given in his paper by the use of the absorption-equation

$$I = I_0 \times 10^{-\alpha x} \tag{12}$$

where I_0 is the intensity of the incident light, I is the intensity of the transmitted beam, x is the thickness of the absorbing layer reduced to standard conditions, and α is the absorption-coefficient. The calculations for absorption by carbon dioxide, water-vapor, and ozone in the upper atmosphere are given in Tables 4, 5, and 6, respectively. For the first two tables, column 1 gives the wavelenth absorbed λ, column 2 gives the absorption-coefficient α, and column 3 gives the transmission through the upper atmosphere $10^{-\alpha x}$.

[10]Physics of the air, p. 38.

[11]RUSSELL, DUGAN, and STEWARD, Astronomy, v. 2, 1927, p. 534.

[12]*Proc. R. Soc.*, v. 82, 1909, p. 43.

TABLE 4—*Absorption by carbon dioxide above 12 kilometers, $x = 44.91$*

(1) λ	(2) a	(3) $10^{-a_x} \times 10^2$
2.4 to 3.0	.0062	52.7
3.0 to 4.2	.0000	100.
4.2 to 4.5	.0303	4.37
4.5 to 12.5	.0000	100.
12.5 to 16.0	.0273	5.92

TABLE 5—*Absorption of water-vapor above 12 kilometers, $x = 14.97$*

(1) γ	(2) a	(3) $10^{-a_x} \times 10^2$ Transmission %
5.0	.000	100.0
5.2	.0185	53.0
5.4	.0315	33.9
5.6	.0658	10.3
5.8	.0915	4.3
5.9	.0995	3.2
6.0	.0797	6.5
6.2	.0315	33.9
6.4	.128	1.2
6.5	.145	0.7
6.6	.1175	1.7
6.8	.0572	14.0
7.0	.0477	19.3
7.2	.0365	28.5
7.4	.0189	52.1
7.6 to 7.8	.00913	73.1
8.0 to 8.1	.00524	83.5
8.1 to 12.0	.0004	98.4
12 to 13	.00129	95.7
13 to 14	.00177	94.1
14 to 15	.00404	87.0
15 to 16	.00549	82.8
16 to 17	.0110	68.6
17 to 19	.0150	59.7
19 to 20	.031	34.4

Table 6 has been prepared to illustrate more fully the calculations for ozone-absorption. Column 3 gives the transmission-ratio 10^{-a_x}, and columns 4, 5, and 6 give the energy-transmission plotted in Figs. 3, 4, and 5, respectively.

Ozone-absorption in the upper atmosphere has been very fully discussed by Fabry[13]. Table 6 is compiled from values for a taken from this paper for $\lambda = 0.64$ and data furnished by Ladenburg and Lehmann[14]. From Fabry's papers we obtain the thickness

[13] *Proc. Phys. Soc.*, v. 39, 1926, p. 1.

[14] *Ann. Phys.*, v. 21, 1906, p. 305.

TABLE 6—*Absorption of ozone above 12 kilometers, x=0.32*

(1) λ	(2) α	(3) $10^{-\alpha_x}$	(4) 219°	(5) 300°	(6) 350°
2.0	.003	.9980	......	.....	000
2.8	.003	.9980	......	.....	000
2.8	.002	.999	......	.....	000
3.3	.011	.992	......	.....	.0004
3.7	.012	.991	......	.....	.00120
4.1	.002	.999	......	.....	.0002
4.75	.118	.917	.00089	.0165	.033
4.98	.044	.968	.0001	.0081	.0153
5.19	.004	.997	......	.0001	.0017
5.57	.000	1.000	......	.....	.0000
5.76	.028	.980	.0002	.0090	.0140
5.94	.040	.971	.0041	.0130	.0220
6.10	.017	.988	......	.....	.0090
6.25	.000	1.000	......	.....	000
6.40	.007	.995	......	.....	.0043
6.63	.008	.994	......	.....	.0053
6.80	.002	.999	......	.....	.0009
7.20	.003	.9980	......	.....	.0019
7.60	.027	.980	.008	.0172	.0196
8.15	.003	.9980	......	.....	.0020
8.65	.046	.965	.0158	.0318	.0328
9.35	.136	.905	.0675	.095	.092
9.55	.215	.854	.109	.146	.139
9.65	.236	.840	.123	.160	.151
9.8	.307	.798	.162	.202	.190
10.0	.281	.813	.152	.186	.172
10.1	.177	.878	.100	.121	.112
10.15	.110	.922	.064	.077	.071
10.4	.055	.996	.0035	.0039	.0035
10.55	.030	.978	.0194	.0216	.0191
10.8	.006	.996	.0036	.390	.0034
11.05	.019	.986	.0130	.0134	.0116
11.35	.030	.978	.0209	.0206	.0176
11.6	.023	.983	.0165	.0156	.0132
11.88	.011	.992	.0079	.0072	.0060
12.2	.007	.995	.0050	.0044	.0036

of the ozone-layer as equivalent to a layer 0.32 cm thick at standard temperature and pressure, and also the statements that this ozone is not uniformly mixed with the air but is found in a concentrated layer above a height of about 80 km. If a uniform concencentration in agreement with values obtained experimentally of 4 per cent ozone to 96 per cent oxygen is assumed, the ozone-layer would extend from the outer limit of the atmosphere to about 80 km. Fabry concludes from his studies that ozone absorbs 4 per cent of the Sun's radiation. This is a very important figure in any calculation of values for the temperature of the outer atmosphere because at 80 km the other gases present radiate little of the absorbed energy because of their very low absorption above this height as is shown by Table 7, where column 1 gives the thick-

ness x of the absorbing gas reduced to standard pressure and temperature; column 2 gives the maximum value of α in the region 2μ to 20μ, and column 3 gives percent of absorption for the maximum absorption-band.

TABLE 7—*Absorption above 80 kilometers*

Gas	(1) x	(2) α maximum	(3) Percentage absorption at maximum
H_2O	6.8×10^{-4}	.145	.023
CO_2	2.1×10^{-3}	.0303	.014
O_3	3.2×10^{-1}	.307	20.2

Table 7 shows at once that above 80 km ozone is roughly a thousand times as effective in radiating energy as water-vapor or carbon dioxide, therefore, unless there is strong absorption and radiation in the infra-red, practically all of the heat absorbed above 70 km must be re-radiated by the ozone. In this connection it should be noted, however, that over 20 per cent of black-body radiation for temperatures below 300°K is in the region of wave-length greater than 20 μ where absorption-coefficients have not been measured.

The exact expression for absorption of diffuse radiation by a plane is obtained as follows: Let E be the total energy passing in one direction through unit area, then

$$E=\int_0^{\pi/2} 2\pi A \sin\phi \cos\phi \, d\phi=\pi A$$

where ϕ is the angle which the radiation makes with the normal to the plane and A is the normal radiation per unit solid angle across unit area. The expression for the light transmitted is then

$$E_t=\int_0^{\pi/2} 2\pi A \sin\phi \cos\phi \, e^{-K/\cos\phi} d\phi=2\pi A\int_0^{\pi/2} \cos\phi \, e^{-K/\cos\phi} d\cos\phi$$

where K is the coefficient of absorption for light normal to the plane. Substituting $x=1/\cos\phi$ gives

$$E_t=2\pi A\int_1^{\infty} x^{-3}e^{-Kx}$$

Values of this integral for different values of K were obtained from Gold's paper (*l. c.*). Table 8 gives comparative values of absorption for normal and diffuse light for values of K varying from 0.01 to 0.1.

TABLE 8—*Normal and diffuse absorption*

K	Normal $(1-e^{-K})\times 10^2$	Diffuse $(1-2\pi\int_0^\infty x^{-3}e^{-Kx})\times 10^2$
.01	1.0	1.9
.02	2.0	3.8
.04	3.9	7.4
.1	9.5	16.7

From Table 8 we see that for small value of K diffuse absorption is double normal absorption, but since normal radiation will be in the same ratio to diffuse radiation, no error in calculations of radiation-equilibrium is introduced by neglecting the factor 2 on both sides of the equation. On the other hand the fact that the radiation transmitted through the atmosphere is not uniform in all directions, and is not black-body radiation, introduces a very important error which could only be eliminated if all factors of absorption, such as cloudiness, haze, etc., were fully known, which is of course impossible. The plan of this paper is to include such factors as are known and can be calculated and from these known factors draw conclusions concerning the whole problem. All radiation and absorption are assumed to be between infinite planes and normal to the surfaces of these planes. This assumption is made to simplify the problem although it is realized that the actual absorption and radiation must always be greater than those assumed.

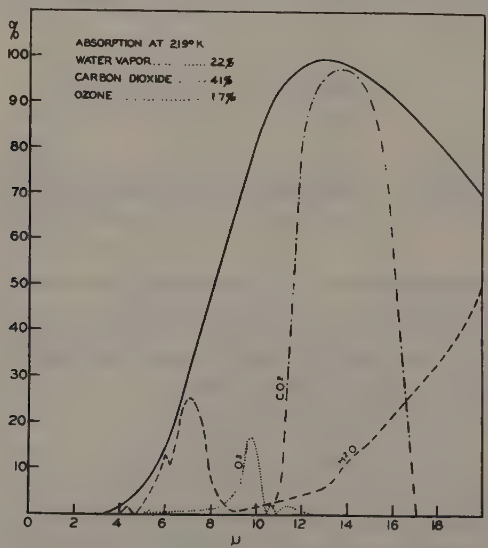

FIG. 3—Absorption and radiation of energy at a temperature of 219°K by a black body and by the water-vapor, carbon dioxide, and ozone of the atmosphere at heights greater than 12 kilometers above the Earth's surface

Figures 3, 4, and 5 are drawn to show black-body radiation and the absorption by H_2O, CO_2, and O_3 gases of the upper atmosphere at the respective temperatures 219°, 300°, and 350°. The dotted line represents ozone-absorption, the broken lines represent water-vapor, and the dot-and-dash lines carbon-dioxide absorption.

The radiation and absorption of Figs. 3, 4, and 5 are summarized in Table 9, where for each temperature column 1 gives the percentage of absorption (A) of black-body radiation and column 2 gives the radiation in ergs (R) by the different gases for the given temperatures. It is to be noted that the efficiency of the water-vapor and ozone decreases with decrease in temperature, but on the other hand the carbon dioxide absorbs most effectively at a temperature of 203° which is approximately the temperature of the base of the

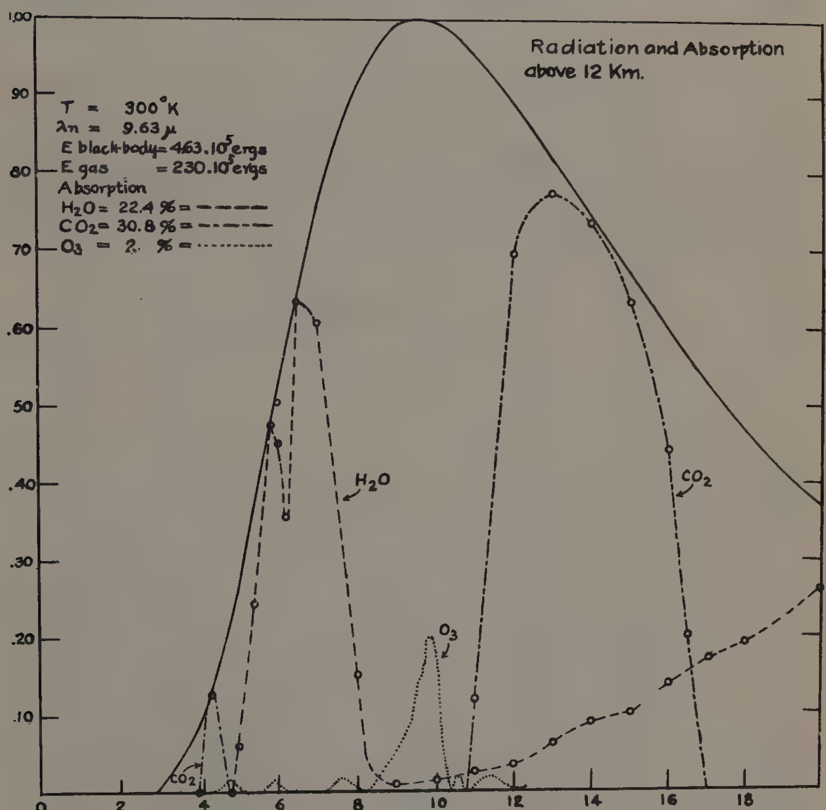

FIG. 4—Absorption and radiation of energy at a temperature of 300°K by a black body and by the water-vapor, carbon dioxide, and ozone of the atmosphere at heights greater than 12 kilometers above the Earth's surface

upper atmosphere over the equator. The figures of column 2 are calculated for radiation in one direction only.

TABLE 9—*Radiation and absorption above 12 kilometers*

Gas	Temperature					
	219°		300°		350°	
	(1) *A*	(2) *R*	(1) *A*	(2) *R*	(1) *A*	(2) *R*
	per cent	ergs	per cent	ergs	per cent	ergs
Black-body	100.	1.31×10^5	100.	4.63×10^5	100	8.57×10^5
Water-vapor	21.7	2.84×10^4	22.4	1.04×10^5	25.	2.14×10^5
Carbon dioxide	41.2	5.40×10^4	30.8	1.43×10^5	27.	2.31×10^5
Ozone	1.71	2.24×10^3	2.01	9.31×10^3	2.3	1.97×10^4

The absorption and radiation energies of Table 9 are effective in warming and cooling the atmosphere above 15 km. Water-vapor and carbon dioxide are of course most effective at 12 km and decrease in importance rapidly with increasing altitude, but according to Fabry ozone reaches its maximum efficiency at about 80 km. Table 10 has been constructed to show the effects of absorption and radiation at different altitudes with 219° radiation from the

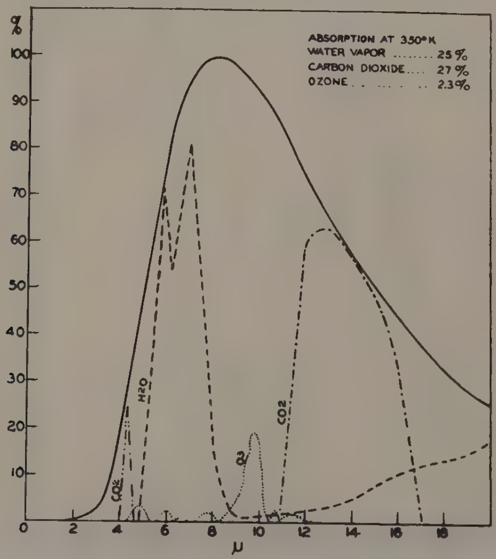

FIG. 5—Absorption and radiation of energy at a temperature of 350°K by a black body and by the water-vapor, carbon dioxide, and ozone of the atmosphere at heights greater than 12 kilometers above the Earth's surface

Earth and with the air at a temperature of 300°K. The ozone-absorption is assumed to be 4 per cent of the total energy from the Sun and at altitudes greater than 80 km. The energy absorbed is $1.35\times10^6\times\cos 50°\times0.04=3.5\times10^4$ ergs per second at noon, or $3.5\times10^4\times8.64\times10^4\times1/\pi=9.56\times10^8$ ergs per day.

Column 1 gives the heights in kilometer (Z); column 2 gives the heat capacity (H) of all the atmosphere above the given altitude in ergs per degree. Values of H are given approximately by $H=p\times10^4$, where p, the pressure, is taken from Table 14. Column 3 gives the energy absorbed in twelve hours of daylight if ozone-absorption alone is considered. Column 4 gives the absorption of radiation from the Earth based on the assumption that black-body radiation at a temperature of 219° is passing out vertically. Column 5 gives the radiation in twelve hours based on an assumed temperature of 300° and vertical radiation.

TABLE 10—*Warming and cooling of the upper atmosphere*

(1)	(2)	(3)	(4)	(5)	(6)	(7)
Z	H in ergs	Absorption at 219° for 12 hours		Radiation in 12 hrs in ergs at 300°K	Temperature-change in degrees per second	
		Solar	Earth		Day	Night
12	2.0×10^9	9.56×10^8	2.4×10^9	1.7×10^{10}	1.1×10^{-5}	1.7×10^{-4}
20	5.81×10^8	9.56×10^8	9.1×10^8	6.5×10^9	3.9×10^{-5}	2.2×10^{-4}
40	2.97×10^7	9.56×10^8	1.7×10^8	1.2×10^9	7.4×10^{-4}	2.9×10^{-4}
60	1.62×10^6	9.56×10^8	1.1×10^8	7.8×10^8	1.4×10^{-3}	1.1×10^{-2}
80	8.92×10^4	9.56×10^8	1.1×10^8	7.8×10^8	2.5×10^{-1}	1.8×10^{-1}
100	5.02×10^3	6.2×10^8	1.4×10^7	9.9×10^7	2.7	3.9×10^{-1}
120	3.38×10^2	3.8×10^8	2.5×10^6	1.7×10^7	2.3×10^1	9.0×10^{-1}
140	2.00×10	1.4×10^8	4.1×10^5	2.8×10^6	1.6×10^2	2.8

The absorption-figures of column 3 are taken from Fig. 6 which shows the absorption of ultraviolet by different thicknesses of ozone which is assumed to be one per cent of the total atmosphere above 80 km. The total area under the solid curve represents ultra-violet solar-radiation. The area under each of the broken-line curves represents absorption per square centimeter by a thickness of ozone at standard conditions given by the figure under the curve.

Table 10 is not given with the purpose of showing the total absorption and radiation of the upper atmosphere, but to show the relation between absorption-coefficients and thickness of the absorbing media. A comparison of the energies of columns 3, 4, and 5 shows that although ozone-absorption and radiation at night is negligible below 40 km, being constant at 1.1×10^8 and 7.8×10^8 ergs, respectively, above this height it predominates, and that whereas at 12 km, ozone-absorption from the Sun is only one-twentieth of 300° radiation by the gases above, at 80 km it is greater, and at 140 km the ozone-absorption amounts to fifty times 300° radiation by the air above. This change in relative absorp-

tion and emission results from the high coefficient of absorption in the ultraviolet where $\alpha>100$ and the relatively low coefficient of absorption in the infra-red where $\alpha<1$ for ozone. Most gases

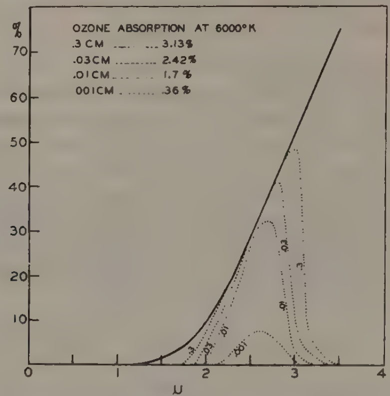

FIG. 6—Absorption in the ultra-violet of 6000° radiation by different amounts of ozone-gas (0.3, 0.03, 0.01, and 0.001 cm) expressed as centimeters of pure gas at standard temperature and pressure

have high coefficients of absorption in the ultraviolet and relatively low coefficients in the infra-red, therefore, we would expect the temperature of the air to increase continually with increased elevation during the day. At heights greater than 150 km we would expect absorption to be independent of the Sun's altitude, that is, the same for all hours of daylight independent of the seasons. In spite of these conclusions the temperature-curves 1 and 3 of Fig. 7 show a constant temperature at high altitudes because it was felt to be useless to project radiation-equilibrium calculations into a region where it is probable equilibrium does not exist, for example ozone-absorption at 140 km would be in equilibrium with its radiation at a temperature of approximately 600°K. This phase of the radiation-absorption problem will be discussed in detail later. Columns 6 and 7 show that the warming and cooling rates are very similar at different altitudes. Above 60 km equilibrium would be established either during the day or during the night very rapidly, even though the total change of temperature were over 100°. Below 20 km temperature-change is slow and equilibrium would not be established during either the day or the night, even though the equilibrium-temperatures varied by as little as 8°. In the calculations for Table 10, the assumption is made that the ozone-absorption, or rather the ultraviolet-absorption all takes place at heights greater than 80 km. The calculations of the following tables and curves are based on the assumption that most of this absorption is made above 60 km and they are valid unless a large fraction of this radiation is absorbed at lower levels.

The following assumptions concerning the temperature of the

atmosphere are represented graphically in Fig. 7. Beyond 60 km the temperature of the atmosphere will be at all times in approximately radiation-equilibrium; from 12 to 25 km the temperature will be nearly independent of day and night changes, but will depend on the wind-activities of the lower atmosphere. Hereafter this will be spoken of as the insulating region. Between these two regions there will be a gradual transition from the condition of radiation-equilibrium to that of constant temperature plus a small increase resulting principally from absorption of the Sun's light during the day.

The curves of Fig. 7 have been drawn to fit the above described conditions. The temperatures plotted from 0 to 20 km are taken from Humphreys "Physics of the Air" (p. 38). Temperature-values for altitudes above 60 km were obtained by assuming a uniform temperature of radiation-equilibrium. Curves 1 and 3 are drawn to represent radiation-equilibrium at noon June 21 and

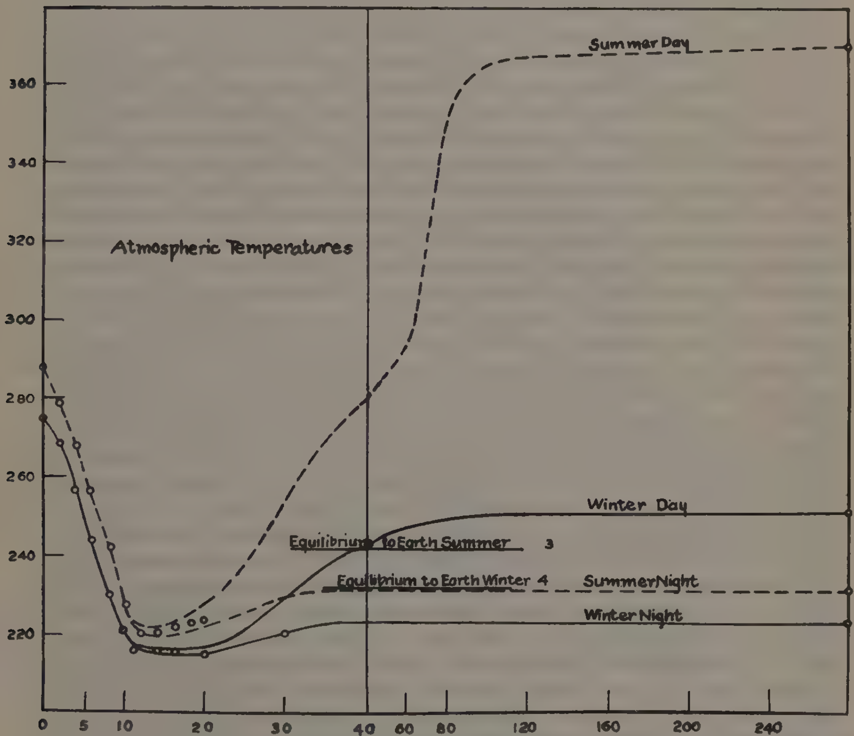

FIG. 7—Absolute temperature plotted against altitude for summer day (1), summer night (2), winter day (3), winter night (4), and equilibrium with the Earth's radiation summer night (5) and winter night (6)

December 21, respectively. Calculations are based on the assumption of heating by ultraviolet absorption of four per cent of the solar radiation above 60 km, ozone-absorption of black-body radiation from the Earth, and cooling by ozone-radiation at the temperature indicated.

Lines 5 and 6 represent temperatures of radiation-equilibrium with the Earth's surface calculated on the assumption that absorption is from below and radiation is in both directions. Radiation-equilibrium at night must be at a lower temperature than that indicated by lines 5 and 6 because of absorption by the cooler insulating region. It is hard to estimate just what the influence of this cooling stratum will be, but it is certain that bands strongly absorbed and emitted above the insulating region are, with the exception of ozone, bands strongly absorbed in the insulating region. On the other hand the ozone-band is very weakly absorbed by the lower atmosphere and we would therefore expect in the upper regions, where ozone-absorption predominates, temperatures closely approximating lines 5 and 6. In fact if ozone only were considered radiation-equilibrium would be at 248° for the summer and 236° for winter night because of the decrease in the efficiency of ozone as a radiator with decrease of temperature as shown in Table 8. Even the ozone-band, however, does not come from the Earth unchanged, but is weakly absorbed in the lower atmosphere. After weighing all of these factors which contribute to the radiation-equilibrium temperature beyond 60 km the assumption is made that equilibrium will be found at an average between equilibrium with radiation from the Earth and the minimum temperature of the insulating region. Lines 2 and 4 of Fig. 7 are drawn in agreement with this assumption. In the region from 20 to 60 km, the temperature at any elevation will depend on radiation-absorption, heat-capacity of the atmosphere for the given region, and the time through which heating or cooling has progressed. The factors were balanced against each other in drawing the curves through this region. These curves show higher temperatures for the region 12 to 20 km than indicated by Dines' (*l. c.*) measurements. The differences are however, slight and the measurements apply only to those parts of the curves which were taken from Humphreys (*l. c.*)

The studies of the absorption and radiation equilibrium-problem have led to a number of interesting conclusions. Figs. 3, 4, and 5, and Table 9 show that in the upper atmosphere carbon dioxide is a more important factor than water-vapor in the absorption of radiation from the Earth. They also show that more than 50 per cent of the radiation which escapes from the Earth originates in this region; therefore, radiation and absorption in this region must be a very important factor in the climate of the Earth since the average temperature of the Earth is controlled by the escape of radiation through the outer atmosphere rather than by the radiation, conduction, or convection from the surface. We would expect then that changes in the carbon-dioxide content

of the upper atmosphere would result in changes of climate. If it were increased, the absorption in the insulating region would be increased and curves 5 and 6 would give lower temperatures from 12 km out. The consequent decrease in the amount of the escaping radiation would of course result in an increase in the temperature of the lower atmosphere. An increase in the temperature of the lower atmosphere would result at once in increased humidity. The increased humidity would lead to an increase in the violence of atmospheric disturbances which would push the limit of the adiabatic temperature-gradient up to higher altitudes and hence lower temperatures with a further decrease in radiation-loss from the Earth. These conclusions point to a condition of unstable equilibrium in the temperature of the Earth's atmosphere. Such a state of unstable equilibrium does exist at the present time since the loss of heat by radiation from the warm tropical regions is much less than the loss from the cooler polar regions.

An observer on Mars measuring the temperature of the Earth with a telescope and sensitive thermocouple would find radiation from the dark equator representing a temperature of a little over 205°K, the temperature at the base of the stratosphere over the equator plus a small amount of radiation received from the warmer strata below; from the dark poles he would receive radiation representing a temperature of 230°, the temperature at the base of the stratosphere in this region. If, for some reason, our climate were made much warmer than it is at the present time, our observer on Mars would not record the increase in temperature, but would observe a spread of the cold equatorial band toward the poles on the dark side of the Earth, and an increase in the brightness of that part of the Earth illuminated by sunlight. On the other hand, if for some reason our climate were to become much colder the Martian observer would record a spread of the warm polar cap toward the equator and decrease in the brightness of the part of the earth illuminated by the sunlight.

These considerations lead to the conclusion that carbon dioxide probably plays a very important part in the control of our climate. In fact it may act like a trigger in controlling the unstable balance of thermal equilibrium of the Earth and comparatively insignificant changes in its mass might result in very violent climatic changes. If the carbon-content of plants of the Earth were to increase by 60 per cent or if the combined action of plant and animal life were to store up an equivalent amount of carbon in the Earth as coal, oil, peat, calcium carbonate, etc., the carbon-dioxide content of the air would be reduced from 0.03 to 0.01 per cent, and radiation from the upper atmosphere would be reduced from 7.6×10^4 ergs to 6.0×10^4 ergs, even if we assume a temperature of 219°K for this region. This reduction alone would amount to a decrease of 6°C in the mean annual temperature of the Earth's surface, which would be equivalent to changing the climate of Memphis, Tennessee, to that of New York City. If we add to this the loss of insulating action of

the carbon dioxide and water-vapor of the lower atmosphere, and the loss resulting from a higher temperature at the base of the upper atmosphere due to the lower water-vapor content of the lower atmosphere, we see at once that under such conditions we might expect ice near the equator.

On the other hand, if we assume that in the past there has been a balance between storing and releasing of carbon by plant and animal life, the consumption of coal, oil, and peat will increase the carbon-dioxide content of the air; for example, the burning of sufficient coal to cover the surface of the Earth with a stratum one millimeter thick, or roughly 800 tons for each person on the Earth, would change the carbon-dioxide content of the air from 0.03 to 0.1 per cent. This would result in an increase in the radiation received from the upper atmosphere from 7.6×10^4 to 9.2×10^4 ergs for a temperature of 219°K. This radiation alone would produce an increase of 6°C in the mean annual temperature of the Earth's surface; to this increase would be added the blanketing effect of the increased absorption in the lower atmosphere and the lower temperatures of the insulating region resulting from the increased violence of atmospheric disturbances accompanying the increased moisture-content of the lower air. Under these conditions we might expect a mild climate even near the poles.

Known absorption-coefficients lead us to expect intense absorption in the ultraviolet and comparatively weak absorption in the infra-red as a general rule, but radiation-equilibrium temperature in an atmosphere warmed by strong absorption and cooled by weak radiation will continually increase with increasing altitude, as is shown by a comparison of columns 3 and 5 of Table 10. We would expect then a continual increase in the temperature of the Earth's atmosphere with increased altitude, but obviously the temperature cannot increase indefinitely.

In the discussion thus far we have considered absorption, temperature-change, and re-radiation as mass phenomena, but at the outer limit of the atmosphere where the mean free-path of the molecule becomes many kilometers absorption of radiation, temperature-change, and re-radiation must be considered not with reference to the mass, but to the individual molecules. Oxygen has a broad absorption-band in the region 1300 to 1900 angstroms[15]. Radiation in this region would, according to the excitation-equation[16], require an excitation-energy greater than $12345/\lambda A=6.5$ volts. We would expect then that an absorbing molecule would undergo a change of energy greater than $1.592\times10^{-12}\times6.5=1.03\times10^{-11}$ erg. Expressed as kinetic energy this is equivalent to a velocity greater than 6.3×10^5 cm/sec. Free-moving molecules started away from the Earth with such velocities would reach altitudes greater that 3000 km. We would expect the ultraviolet absorption to be accompanied by chemical activity such as the formation and

[15] LYMAN, Spectroscopy of the extreme ultraviolet, 1914, p. 68.

[16] FOOTE AND MOHLER, Origin of the spectra, 1922, p. 228.

decomposition of ozone, hydrogen peroxide, water-vapor, and the oxides of nitrogen[17]. These changes involve energies much below the excitation-energies of the radiation absorbed, but energies nevertheless which involve heat-transfers of 10,000 to 100,000 calories per gram-molecule of the gases. Since these changes occur at the limit of the atmosphere where the free-energy of a reaction may be shared by only two or three molecules, the energies of these molecules may be equal to the average energy of gas-molecules at temperatures ranging from 10,000 to 200,000°C.

We must conclude then, that when sunlight falls on our atmosphere above 300 km, where the mean free-path is great, the energy-distribution among molecules, atoms, and ions will differ very radically from that given by a Maxwellian curve and that there will be many more high-energy atoms than a chance distribution would indicate. We can hardly draw a picture of the mechanics of energy-transfers associated with the ionization, excitation, and chemical dissociation resulting from absorption of ultraviolet light at heights greater than 300 km, but of a few things we are certain: Molecules, even in free spaces, absorb light-energy and become ionized; the energies involved are great compared with the energy of temperature-changes under ordinary conditions of gas-pressure; energies of recombination are dissipated in increasing the temperature (velocity) of the surrounding gas-molecules (this dissipated energy might be shared by only one or two atoms), and finally the mean free-path of the molecule might be infinite. We would then, not expect equilibrium in the atmosphere beyond 300 km. A detailed discussion of what we would expect is beyond the purpose of this article, but a brief summary of probabilities should be of interest. The molecular density in the region beyond 300 km will not follow ordinary gas-laws, but will depend on absorption of light and chemical recombination below. Molecules and neutral atoms will receive high velocities from recombination-collisions at low altitudes (300 to 400 km); they will shoot away from the Earth to great distances where many of them will be ionized; the fall of the ions back to the Earth will be greatly hindered and directed toward the poles by the Earth's magnetic field. Peterson[18], in discussing the fall of ions into the Earth's atmosphere has reached the conclusion that they bring with them an energy equal to roughly one ten-thousandth of the solar energy absorbed by the atmosphere in the ultraviolet region. This is, of course, negligible as a factor in determining the temperature of the upper atmosphere, although it may be far from negligible in a discussion of any phenomenon of ionization or excitation for this region. The loss of molecules from the Earth's atmosphere is probably independent of ordinary temperature-effects, but depends on coefficients for the absorption of light and the mechanics of recombinations.

[17]Luckiesh, Ultraviolet radiation. [18]*Physik. Zs.*, v. 28, 1927, p. 510.

(*To be continued*)

A NEW FIELD-MAGNETOMETER

A new field-magnetometer, designed by Dr. F. E. Smith, and constructed by the Cambridge Instrument Company Limited, has been taken into use by the Ordnance Survey of Great Britain.

This magnetometer is the same in principle as the Schuster-Smith coil now in use at the Abinger Magnetic Observatory, Surrey, England. It consists of twin coils of wire, 40 cm in diameter and about 20 cm apart, mounted on a rigid metal framework over a heavy base upon a tripod. A current of about 0.1 ampere, measured by balancing a standard cadmium cell against a known portion of the resistance in circuit, serves, when passed through the coils, to neutralize the Earth's magnetic field in the latitudes of the British Isles. The observation for horizontal force consists of a reading of the undisturbed position of a magnet-system at the centre of the axis of the coils, followed by a reading of its position when the current is producing a field nearly equal to, but not quite in the direction of, the Earth's field, so that an elongated right-angled triangle of forces exists. The relation

$$H = FC \sec \theta$$

then exists between the horizontal force, the constant F of the coil, C the current, and θ the angle between the two positions of the telescope. The latter is made to give auto-collimation of its central wire in the focal plane by means of a small optically worked silvered glass cube forming part of the rigid magnet-system. In the above-described two operations the telescope reads first on one face of the cube and then on an adjoining one, so that it only has to be swung through the small angle θ (4° to 12°) whereas the magnet-system swings through $(90° - \theta)$. There is a small temperature-correction, applied jointly by means of a graph, depending on the temperature-coefficients of the standard cell, the resistances, and the constant of the coil. Values of H correct to about two gammas can be obtained at intervals of about three or four minutes with the instrument. A very interesting feature of the magnet-system is that instead of being suspended it is completely immersed in light spirit and tries to float, being held down by a jewel-cup which comes into contact with a jewel-point on the system. The upward force is only a few per cent of the weight of the system, and may be adjusted by adding or removing a small rider. Torsion is completely eliminated by this device, and friction is overcome by maintaining a gentle tapping on the container during observations. The apparatus, though designed primarily for the determination of horizontal force, has also been used in the field for determining declination. The results have been consistent, though slightly less accurate in individual readings of declination than those made with a Kew-pattern magnetometer. Some small modifications to the instrument will be carried out to improve it in this respect. About 30 field-stations were surveyed in England and Wales during May and June with this instrument.

ORDNANCE SURVEY OFFICE

Southampton, England, September 17, 1928

PROVISIONAL SUNSPOT-NUMBERS FOR SEPTEMBER AND OCTOBER 1928

(Dependent alone on observations at Zürich Observatory)

Day	September	October	Day	September	October
1	63	65	16	. .	80
2	47	69	17	46(?)	74
3	76	58	18	. .	73
4	73	45	19	85	46
5	57	42	20	103	62
6	47	25	21	98	. .
7	55	41	22	109	. .
8	96	56	23	115	76
9	89	52	24	130	74
10	85	67	25	144	65
11	. .	92	26	136	30
12	89	71	27	152	22
13	. .	. .	28	111	28
14	54	79	29	107	22
15	56	70	30	111	. . .
			31		48

Mean for September (26 days): 89.8
Mean for October (27 days): 56.7

Zürich, Switzerland A. WOLFER

PRINCIPAL MAGNETIC STORMS

OBSERVATOIRE DE TSINGTAO, JUILLET 1928

(*Latitude 36° 04.'3 N.; longitude 8° 01' 5 E. de Gr.*)

Temps moyen de Greenwich			Ecarts		
Commencement		Fin	Decl.	Comp. hor.	Comp. vert.
1928	*h m*	*j h m*	′	γ	γ
7 juillet	23 23	8 20 29	43.2*	989	562

*La courbe sort du papier.

Remarque—C'est une perturbation extraordinaire telle que nos instruments n'ont pas enregistré de pareille depuis leur installation. Elle est caracterisée surtout par un commencement très brusque et une amplitude extrêmement rapide. A 16^h du 8 la perturbation s'est déjà adoucie, mais de petites oscillations ont continué jusqu'à 14^h du 9.

P. J. TSIANG, *Directeur*

CHELTENHAM MAGNETIC OBSERVATORY
JULY TO SEPTEMBER, 1928[1]

(Latitude 38° 44′.0 N.; longitude 76° 50′.5 or 5ʰ 07.4ᵐ W. of Gr.)

Greenwich mean time							Range		
Beginning			Ending				Decl'n	Hor. int.	Vert. int.
1928	*h*	*m*	*d*	*h*	*m*			γ	γ
July 7	23	27	8	11	08		240.2	1270*	642*
Sep. 7	13	45	8	09	..		33.8	144	111

*Passed off sheet.

GEO. HARTNELL, *Observer-in-Charge*

SITKA MAGNETIC OBSERVATORY
JULY TO SEPTEMBER, 1928[1]

(Latitude 57° 03′.1 N.; longitude 135° 20.1′ or 9ʰ 01.3ᵐ W. of Gr.)

Greenwich mean time						Range		
Beginning			Ending			Decl'n	Hor. int.	Vert. int.
1928	*h*	*m*	*d*	*h*	*m*		γ	γ
July 7	23	00	10	02	00	329.0	1331**	900**
July 21	10	..	22	10	00	169.0	1194	702*
Aug. 4	17	06	6	02	..	68.1	722	528
Aug. 25	22	37	27	12	..	143.1	1329**	728*
Sep. 3	8	54	3	24	..	100.2	685	529*
Sep. 7	13	46	9	05	..	88.6	895	703*
Sep. 19	9	09	19	23	..	77.5	442	563
Sep. 24	16	27	26	09	..	64.0	428	406

*Curve went off paper in one direction. **Curve went off paper in both directions.

July 7-10, 1928—This storm was one of the most active ever recorded at the Sitka Observatory. It began at 23ʰ 13ᵐ with the magnetic elements more or less active for several hours before that time. From 23ʰ 13ᵐ, July 7, to 23ʰ 44ᵐ rapid oscillations occurred in D and H while the fluctuations in Z were much smaller. At the latter time all of the elements began changing irregularly and fast and from then on the record was an almost unintelligible mass of faint lines and dots. With only occasional places where some of the elements can be identified this continued until 14ʰ on July 8. At that time the H reserve-spot came back on the magnetogram after being off a considerable portion of the storm, while for several hours the Z, H, and D reserve-spots were moving almost entirely across the magnetogram. The main features of the storm were the unusually low values of H during most of the period of greatest activity; the abnormally high values of Z during the first part of the storm, going beyond the edge of the magnetogram a

[1]Communicated by E. Lester Jones, Director, United States Coast and Geodetic Survey.

number of times, with unusually large and fast oscillations in the latter part of the storm, and the unusually low values of D.

July 21-21, 1928—This was relatively a small magnetic storm but it was very active between 8^h and 10^h on July 22.

August 25-27, 1928—This storm has a very definite point of beginning, $22^h\ 37^m$, July 25. The storm was small up to 5^h, July 26, when the elements began to make large rapid changes which lasted until 14^h. From then until 2^h, July 27, the storm was small but at the latter time the large rapid oscillations began again and lasted until 14^h. At this time the curves became normal almost as abruptly as the storm began. In one place a very rapid change in H can be followed. On July 26 at $6^h\ 43^m$ and $8^h\ 59^m$ the H-reserve-spot went off the bottom of the magnetogram with a value of H as 14716 and between these two points, at $8^h\ 51^m$, the H-spot was just above normal with a value of 15531, thus making a change greater than 815 gammas in eight minutes.

F. P. ULRICH, *Observer-in-Charge*

WATHEROO MAGNETIC OBSERVATORY
JULY, 1928

(*Latitude 30° 19′.1 S.; longitude 115° 52.′6 or* $7^h\ 44^m$ *E. of Gr.*)

Greenwich mean time			Range		
Beginning		Ending	Decl'n	Hor. int.	Vert. int.
1928	*h m*	*d h m*		γ	γ
July 7	22 14	8 17 ..	64.5	550	300+

July 7, 1928—This was a severe magnetic storm. Between 22^h and 23^h (G.M.T.) on July 7 the magnetic elements began to depart markedly from the normal curve, and within an hour all three elements showed large and rapid fluctuations. From $23^h.5$ on July 7 to 7^h on the following day was the period of greatest severity of the storm, the oscillations of all three elements being so rapid as to scarcely leave a record on the photographic trace. The declination was especially disturbed and the H-trace was greatly depressed during the last half of the period.

From 7^h to 11^h on July 8, the traces were characterised by fluctuations of a longer period than those registered in the first half of the storm, with the exception of the H-trace which was still further depressed with large and rapid variations. The Z-trace also reached its lowest point during this period in contrast with the D, which attained a maximum value at $10^h\ 44^m$ and at which time all traces showed a sudden general recovery.

Unsettled conditions remained till 19^h, after which the elements were only slightly subnormal. The storm was notable therefore for its short duration, 19 hours, and great severity.

H. F. JOHNSTON, *Observer-in-Charge*

HUANCAYO MAGNETIC OBSERVATORY

AUGUST TO SEPTEMBER, 1928

(Latitude 12° 02′.7. S.; longitude 75° 20′. 4 or $5^h 01^m$ W. of Gr.)

Greenwich mean time					Range		
Beginning			Ending				
					Decl'n	Hor. int.	Vert. int.
1928	*h*	*m*	*d*	*h*	*m*	′	γ	γ
Aug. 4	17	07	5	22	06	6	298	14
Aug. 25	22	35	27	21	..	6.9	356	29
Sep. 7	13	44	9	06	..	9.7	372	21
Sep. 18	15	42	19	20	..	5.1	456	28
Sep. 24	16	23	25	20	..	4.5	355	20

August 4, 1928—At approximately 12^h on August 4, a mild magnetic storm began with a moderate disturbance in the horizontal intensity and the declination, and at $17^h 07^m$ there was a sharp increase in horizontal intensity of 79 gammas in 5.5 minutes. The vertical intensity and the declination also showed a slight change at this time, but were only very slightly disturbed during the period of the storm. On August 4, the horizontal intensity was only moderately disturbed, but on August 5, beginning at 0^h the intensity was low and during the daily maximum the trace showed a marked saw-tooth appearance. The disturbance ended rather abruptly at $22^h 06^m$ on August 5.

August 25, 1928—On August 25 at $22^h 35^m$ there was a small abrupt increase of 21 gammas in the horizontal intensity, and during the early hours of August 26 several moderate slow changes were recorded During the daily maximum on this day the trace became very jagged in appearance, but the largest movement was an increase of 69 gammas in 6 minutes beginning at $17^h 17^m$. During the early part of August 27 the horizontal intensity was unusually low but the trace was only slightly disturbed. At $6^h 45^m$ it increased 139 gammas in 34 minutes almost to the normal value for that time of day but until the end of the storm was in general below normal. The vertical intensity and the declination were only slightly disturbed during the storm.

September 7, 1928—At $13^h 44^m$ on August 7 there was a sharp decrease of 27 gammas in the horizontal intensity followed immediately by an increase of 152 gammas in a total of 6 minutes. The declination and the vertical intensity showed marked though small increases at the same time and small rapid fluctuations for about 8 hours. The horizontal intensity went through large rapid changes during the first hour and a half of the storm, the greatest being a decrease of 151 gammas in 5 minutes beginning at $14^h 54^m$. This period was followed by about 6 hours of smaller though equally frequent fluctuations. After 21^h on September 7, the changes in all

the elements were less frequent and less marked, but there was a moderate disturbance in the horizontal intensity during the daily maximum on September 8 and the intensity was subnormal until the end of the storm.

September 18, 1928—On September 18 at $15^{h}\,42^{m}$ a magnetic storm began suddenly in all the elements, the horizontal intensity showing a rapid decrease of 22 gammas followed by an increase of 129 gammas in a total of 6 minutes. The sharpest part of the storm lasted until about 21^{h}, followed by a period of relative quiet during the night until just before 13^{h} on September 19, when a similarly disturbed period began and lasted until the end of the storm.

September 24, 1928—At $16^{h}\,23^{m}$ on September 24 the horizontal intensity showed a rapid increase of 149 gammas in 3 minutes, and marked increases were also recorded for the declination and the vertical intensity beginning one minute later. Except for the first rapid jump, the storm was mild and only moderate though rapid changes were recorded by all the elements during the daily maxima of the two days. The horizontal intensity was low for a few hours after the end of the storm but only slightly disturbed.

All times given are Greenwich civil mean time.

PAUL G. LEDIG, *Observer-in-Charge*

REVIEWS AND ABSTRACTS

(See also pages 187 and 209)

HOFFMANN, G., UND F. LINDHOLM: *Registrierbeobachtungen der Hessschen Ultra-γ-Strahlung auf Muottas Muraigl* (2456 *m*). Beitr. Geophysik, Leipzig, Bd. 20, Heft 1, 1928 (12-54). [Authors' summary.]

The increase in the ionizing effect of penetrating radiation by the use of compressed carbonic-acid gas for filling the ionization-chamber together with an electrometric compensating arrangement enables an accuracy of one to two per cent to be attained. Continuous records of penetrating radiation are carried out at Koenigsberg (at sea-level) and at Muottas Muraigl (2456 m) in the Upper Engadine, with a lead screen for shutting out the softer rays from around. The intensity varies with the changes in barometric pressure, but in an irregular manner. No simple variation of intensity according to sidereal time exists. It will be possible to draw further conclusions only after new and extensive obser-vavations have been made. By measuring the absorption-power of different protecting screens, diffusion-effects are found which confirm the character of Hess radiation as ultra-gamma-radiation.

NOTES

(See also page 222)

35. *Magnetic Work in Siam*—We learn from the Report of the Royal Survey Department of Siam for 1925 to 1926, that it has not yet yet been found possible to establish a magnetic base-station although the project was sanctioned several years ago. In the meantime magnetic activity has been confined entirely to field-observations. During the year October 1, 1925, to September 30, 1926, six new stations and ten repeat-stations were occupied.

36. *Cruise VII of the Carnegie*—The *Carnegie* left Barbados, British West Indies (see this JOURNAL, v. 33, p. 178) on October 1, 1928, and arrived at Colon, Canal Zone, on October 11, having experienced en route fine weather with occasional squalls accompanied with heavy rain and thunder and lightning. On the passage the usual scientific program was carried out. The vessel passed through the Canal on October 11. After repairs she left Balboa October 25, bound for Easter Island where she was expected to arrive about December 10. Radio messages, which are being regularly received, indicate that the work is progressing well. On account of delay it was decided to modify the proposed route so as to shorten somewhat the loop to Easter Island, passing via 10° south latitude and 110° west longitude, instead of swinging northward so as to reach the parallel of 10° north latitude at about 100° west longitude, as tentatively planned (see route-map of proposed course, this JOURNAL, v. 33, p. 3). According to a radio message dated November 15, the vessel had reached 3° 15′ south latitude and 99° 50′ west longitude, and on November 19, 4° 35′ south latitude and 105° 10′ west longitude. On November 26, the vessel's position was 21° 45′ south latitude, 114° 30′ west longitude, and on December 1, 29° south and 119° west. Easter Island was reached December 6 and after shore-observations the party sailed December 12 for Callao. December 23 the radioed position was 39° south and 103° west, the vessel having been driven south by steady northeast winds. The *Carnegie* is due at Callao early in January.

37. *Aurora Australis, July 7, 1928*—In connection with the brilliant display of the Aurora Borealis described in the September issue of this JOURNAL, it is of interest to note that a corresponding manifestation of the Aurora Australis was observed in various places in Australia. It was visible at Melbourne as a glowing pink arc between 18^h and $18^h\ 30^m$ local standard time, after which it gradually faded. A report from Sydney states that the phenomenon was witnessed at that place for a considerable time. There was a haze which stretched across the sky from the southern to the western horizon and had the appearance of a rose-tinted cloud; then shortly after $20^h\ 30^m$ standard time a vivid display, light greenish-blue in color, broke out and in contrast against the rose-tinted cloud was very marked. After about five minutes the display lost its brilliance and gradually faded away. It is stated that at Adelaide the aurora was one of the best seen for many years.

38. *Erratum, June 1928 Terrestrial Magnetism*—Remarques à propos des mesures magnétiques de M. Parkinson etc., par Prof. L. Palazzo, page 106 6e ligne, le premier terme de la formule de D; au lieu de 10° 21′.9 lire 10° 28′.9.

39. *Personalia—Wilhelm Wien*, professor of experimental physics in the University of Munich, editor of *Annalen der Physik* and of the *Handbuch der Experimentalphysik*, died on August 31, 1928, at the age of sixy-four years.

Thomas Chrowder Chamberlin, emeritus professor of geology in the University of Chicago, died on November 15, 1928, at the age of eighty-five years.

Sebastian J. Mauchly, physicist on the staff of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington since 1914 and until 1928 chief of its Section of Terrestrial Electricity, died December 24, 1928, aged fifty years, at his home in Chevy Chase, Maryland, after a long illness.

Clarence A. George, Junior Engineer, has taken over the field-work in the southeastern states from *S. A. Deel*. The work will extend from Virginia to Florida and thence to Alabama.

Franklin P. Ulrich has returned to Sitka from field-work in the interior of Alaska, and has resumed charge of the observatory after a very successful season as in addition to occupying the repeat-stations on the Yukon River, he occupied three on the northern tributaries and Iditarod to the south of the Yukon. He went from Fairbanks to Cordova by way of the Richardson Highway and occupied three stations en route.

LIST OF RECENT PUBLICATIONS

By H. D. Harradon

A—Terrestrial and Cosmical Magnetism

Agincourt and Meanook Observatories. Results of observations at the Canadian Magnetical Observatories, Agincourt and Meanook. The year 1923. Prepared by W. E. W. Jackson under the supervision of Sir Frederick Stupart. Ottawa, F. A. Acland, 1928 (40 with 5 pls.). 29 cm.

Aldrich, H. R. A demonstration of the reflection of geologic conditions in observed magnetic intensity. New York, N. Y., Amer. Inst. Min. Metall. Engin., 1928, 14 pp. 23 cm.

Baldit, A. Mesures magnétiques dans le sud-ouest de la France. Paris, C.-R. Acad. sci., T. 187, No. 13, 1928 (543-545).

Bock, R. Ueber die Schmidtsche Methode der Bestimmung der Parameter von Stahlmagneten. Zs. Geophysik, Braunschweig, Jahrg. 4, No. 5, 1928 (227-236 mit 9 Abb.).

Chapman, S. The daily terrestrial magnetic variations, and the Sun's magnetic field. Nature, London, v. 122, Oct. 13, 1928 (572). [Preliminary remarks regarding article by R. Gunn in Phys. Rev., v. 32, July, 1928, pp. 133-141.]

Chree, C. The value of magnetic investigations in New Zealand and Samoa. N. Z. J. Sci. Tech., Wellington, v. 10, No. 2, July, 1928 (97-100).

Clough, H. W. The 28-month period in solar and corresponding periods in magnetic and meteorological data. Washington, D. C., Mon. Weath. Rev., v. 56, July, 1928 (251-264).

Copenhagen, Det Danske Meteorologiske Institut. Magnetisk aarbog, 1ste del: Danmark (undtagen Grönland)—Annuaire magnétique, 1ère partie, le Danemark (excepté le Groenland). 1926. Köbenhavn, G. E. C. Gad, 1928, 15 pp. 32 cm.

DE BILT, METEOROLOGICAL AND MAGNETICAL OBSERVATORY. Annuaire. Soixante-dix-huitième année. 1926. B. Magnétisme terrestre. (K. Nederlandsch Met. Inst. No. 98.) Utrecht, Kemink & Zoon, 1927 (xi+24). 34 cm.

GRAVE, D. Sur les anomalies magnétiques. Leningrad, C.-R. Acad. sci., No. 16-17, 1928 (316-318). [Texte russe.]

GUNN, R. Note on the radial magnetic gradient of the Sun. Science, New York, N. Y., N. S., v. 78, Sept. 21, 1928 (273).

HAALCK, H. Zur Frage nach der Ursache von lokalen gravimetrischen und erdmagnetischen Störungen und ihre wechselseitigen Beziehungen. Zs. Geophysik, Braunschweig, Jahrg. 4, Heft 5, 1928 (209-219).

HAMBURG, DEUTSCHE SEEWARTE. Fünfzigster Jahresbericht über die Tätigkeit der Deutschen Seewarte für das Jahr 1927. Hamburg, 1928, 42 pp. 27 cm. [On pp. 11-16 is a report of the Abteilung II/IV (Instrumente und Schiffslaternen; Erd- und Schiffsmagnetismus; Zeitdienst).]

INDIA, SURVEY OF. Geodetic report. Volume I. From 1st October 1922 to 30th September 1925. Published by order of Colonel Commandant E. A. Tandy, R. E., Surveyor General of India. Dehra Dun, Geod. Branch Office, 1928 (xii+323 with 16 charts). 25 cm. [Contains results of magnetic observations at Indian observatories for 1922-1923. The values for Toungoo and Kodaikanal for 1923 embrace the first nine months as the magnetic observatory at Dehra Dun was the only one kept in operation throughout the year. This observatory was transferred to the control of the Officer-in-Charge, Computing and Tidal Party. The values of the magnetic elements at Dehra Dun for 1924 are also given.]

KOENIGSBERGER, J. Ueber die bei lokal vergleichenden magnetischen Messungen der Vertikalintensität anzustrebende Genauigkeit. Zs. Geophysik, Braunschweig, Jahrg. 4, Heft 5, 1928 (236-245).

LONDON, METEOROLOGICAL OFFICE. Annual report of the director of the Meteorological Office presented by the Meteorological Committee to the Air Council for the year ended 31st March 1928. London, H. M. Stationery Office, 1928, 46 pp. 24 cm. [Contains brief reports on Kew, Eskdalemuir, Lerwick, and Valentia observatories.]

The observatories' year book 1926 comprising the meteorological and geophysical results obtained from autographic records and eye observations at the observatories at Lerwick, Aberdeen, Eskdalemuir, Cahirciveen (Valentia Observatory), and Richmond (Kew Observatory), and the results of soundings of the upper atmosphere by means of registering balloons. London. H. M. Stationery Office, 1928, 411 pp. 31 cm.

LYOT, B. Magnétographe à inscription photographique visible sans développement. Paris, Bul. soc. astr. France, 42° année, août 1928 (402-405).

MCFARLAND, W. N., and R. W. KNOX. Magnetic declination in Texas in 1927. Washington, D. C., Dept. Comm., U. S. Coast Geod. Surv., Ser. No. 417, 1928 (73 with 1 isogonic chart). 23 cm.

MADILL, R. G. Magnetic work of the Dominion Observatory. Toronto, J. R. Astr. Soc. Can., v 22, Sept., 1928 (255-279 with illus.) [A brief survey of the development of the science of terrestrial magnetism followed by a historical account of the work accomplished in this field in Canada. It is stated that, since the systematic scientific survey of Canada was begun in 1907 by the Dominion Observatory, 984 stations, of which 183 are repeat-stations, have been occupied. A table showing the geographical distribution of these stations (1907-1927) and a summary of the magnetic results obtained during the period 1921 to 1923, appear at the end of the article.]

MAGNETIC STORM. The magnetic storm and aurora of July 7-8, 1928. Washington, D. C., Mon. Weath. Rev., v. 56, July, 1928 (280-282).

MAURAIN, Ch. Sur l'orage magnétique du 7 au 8 juillet 1928. Onde Electrique, Paris, 7e année, août 1928 (363-364).

MAURITIUS, ROYAL ALFRED OBSERVATORY. Results of the magnetic and meteorological observations for the months of July to December, 1927 (new series, v. 13, pts. 7-12, pp. 107-215). Port Louis, Govt. Press, 1927. 34 cm.

Annual report on Royal Alfred Observatory for the year 1927 (R. A. Watson, Director). Port Louis, Govt. Press, 1928, 3 pp. 34 cm. [Contains mean values of the magnetic elements for the year 1927.]

MOIDREY, J. DE. Études sur le magnétisme terrestre 1877-1927, résumées par J. de Moidrey, S. J. Fascicule VI. Chang-Hai, Imprimerie de la Mission Catholique, 1928, (47 avec 7 pls.) 32 cm. [Ce fascicule contient six études consacrées aux sujets suivants: (1) Perturbations à début progressif-déclinaison occidentale, composante horizontale; (2) Amplitude absolue de la composante horizontale. Marche mensuelle lunaire; (3) Effet de la distance de la Lune sur l'amplitude diurne; (4) Révision des mesures de la composante horizontale à Lu-kia-pang, 1908-1922—mesures absolues, moyennes diurnes, moyennes mensuelles, composantes géographiques; (5) Variation annuelle du nombre des jours calmes· (6) variation annuelle du nombre des jours troublés.]

MOKROVIĆ, J. Razdioba glavnih elemenata zemaljskoga magnetizma u Kraljevini Srba, Hrvata i Slovenaca. Zagreb, Izdanje Komande Vazduhoplovstva, 1928 (32 za 2 karte). 23 cm. [Distribution of the terrestrial-magnetic elements in Jugo-Slavia. An introduction giving a brief exposition of the purpose of the work is followed by a table containing results of magnetic observations made during the period 1806-1918 at different points on the territory of Jugo-Slavia. These values, reduced to the epoch 1927.5, are given in another table on the basis of which the isomagnetic charts of D, H, and I forming part of the pamphlet, have been constructed for use until more accurate data may be obtained by a systematic magnetic survey of the entire country. At the end of the paper the author discusses briefly the importance and utility of magnetic charts.]

NEVIÈRE, J. Première contribution à l'étude du magnétisme en Haute-Volta. Paris, Bul. Comité d'Etudes hist. sci. de l'A.O.F., T. 11, No. 3, 1928 (485-499). [Values of the magnetic declination reduced to epoch January 1, 1926, are given for 46 stations in the Haute-Volta.]

NEWTON, H. W. The Sun's cycle of activity. London, Q. J. R. Met. Soc., v. 54, July, 1928 (161-173). [Contains discussion of the relationship between sunspots and terrestrial-magnetic phenomena.]

NEW ZEALAND. Eighth annual report of the Government of New Zealand on the administration of the Mandated Territory of Western Samoa for the year ended the 31st March, 1928. Wellington, W. A. G. Skinner, Govt. Printer, 1928 (54 with maps and illus.). 34 cm. [On pp. 26-28 is an account of the work of the Apia Observatory.]

NEW ZEALAND, DEPARTMENT OF LANDS AND SURVEY. Annual report on surveys for the year ended 31st March 1928. Wellington, W. A. G. Skinner, Govt. Printer, 1928, 21 pp. 34 cm [Contains brief report on the Christchurch Magnetic Observatory with table showing the mean annual values of the magnetic elements at Christchurch from 1920 to 1927 inclusive.]

NICHOLSON, S. B., AND T. W. ROBINSON. Summary of Mount Wilson magnetic observations of sunspots for May and June, 1928. Pub. Astr. Soc. Pacific, San Francisco, Cal., v. 40, Aug., 1928 (256-259).

OTTAWA, TOPOGRAPHICAL SURVEY. Annual report of the Topographical Survey of Canada for the fiscal year ended March 31, 1927. Ottawa, F. A. Acland, 1928 (30 with illus. and 4 maps). 25 cm. [On pp. 18-20 is a brief account of the magnetic survey-work.]

ROSÉ, N. Problemy izuchenia zemnogo magnetisma na territorii Iakutii. (Problems in the study of terrestrial magnetism in Yakutia.) Matériaux de la Commission pour l'Etude de la République ASS Iakoute, Livr. 11, (183-195 with 1 map). Leningrad, Acad. sci., 1928.

SCHMIDT, Ad. Ergebnisse der magnetischen Beobachtungen in Potsdam und Seddin im Jahre 1926. Berlin, Veröff. met. Inst., Nr. 356, 1928 (40 mit 15 losen Kurvenblättern). 33 cm.

Der Einfluss des Mondes auf die erdmagnetischen Elemente in Potsdam und Seddin während der Jahre 1905-1924. Berlin, Veröff. met. Inst., Nr. 357 (Arch. des Erdmag. Heft 7), 1928 (25-80).

SODANKYLÄ. Ergebnisse der Beobachtungen des Magnetischen Observatoriums zu Sodankylä im Jahre 1924. Von H. Hyyryläinen. (Veröff. Mag. Observatoriums der Finnischen Akad, Wiss. zu Sodankylä, Nr. 11.) Kuopio, Osakeyhtiö Kirjapaino Sanan Valta, 1928 (55 mit 2 Tafeln). 29 cm.

SOUTHAMPTON, ORDNANCE SURVEY. Ordnance Survey physical map of England and Wales. Magnetic edition. Lines of equal magnetic declination based on observations by G. W. Walker in 1915, and the Ordnance Survey 1925-8, and adjusted to values for June 1928. Scale 1.014 inches to 16 statute miles = 1:1,000,000. Southampton, Ordnance Survey Office, 1928. 75 x 57 cm.

STEARN, N. H. A background for the application of geomagnetics to exploration. New York, N. Y., Amer. Inst. Min. Metall. Engin., 1928, 28 pp. 23 cm. Abstract: Min. Metall., New York, N. Y., v. 9, Sept., 1928 (388-399).

VENSKE, O. Die Mondperiode der erdmagnetischen Vertikalkomponente nach den Registrierungen des Potsdamer Magnetographen in den Jahren 1891-1905. Berlin, Veröff. met. Inst., Nr. 357 (Arch. des Erdmag. Heft 7), 1928 (2-23).

WATKINS, H. G. The Cambridge Expedition to Edge Island. London, Geog. J., v. 72, Aug., 1928 (117-143). [Appendix II contains an account of the magnetic observations by the physicist of the party, R. v. d. R. Woolley. Absolute values of declination and horizontal force at seven stations are given as also a table showing the secular change of D and H at eight points as derived from a comparison with Russian observations made in 1898. The same data are published in *Terr. Mag.*, v. 32, 1927, pp. 147-150.]

WEINBERG, B. P., i N. N. TRUBIATCHINSKY. Magnitye opredeleniia A. I. Vilkitskogo i ego sotrudnikov 1882-1901 gg. Zap. gidrograph., Leningrad, T. 54, 1928 (37-58). [Magnetic determinations of A. I. Vilkitsky and his collaborators 1882-1901. Text in Russian.]

B—Terrestrial and Cosmical Electricity

ABSALOM, H. W. L. Unusual thunderstorm phenomena. Met. Mag., London, v. 63, Aug., 1928 (163-164).

BEALS, C. S. The Aurora Borealis. Abstract: Toronto, J. R. Astr. Soc. Can., v. 22, Sept., 1928 (298-299).

BENNDORF, H., UND V. F. HESS. Luftelektrizität. Sonderdruck aus Müller-Pouillet, 11. Aufl., Bd. V, 1, 1928, 519-661.) Braunschweig, Verlag von Friedr. Vieweg u. Sohn.

BOYS, C. V. Progressive lightning. Nature, London, v. 122, Sept. 1, 1928 (310-311).

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